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THE EVOLUTION OF METEOROLOGICAL INSTITUTIONS IN THE UNITED STATES

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The object of this paper is to outline the stages in the growth of the organizations that have dealt with climate and weather in the United States of America and to present a chronological bibliography.

It should be noted that there has been mutual reaction of the growing institutions and the growing science of meteorology. The invention of the electric telegraph, after institutions and science were well founded, acted as a powerful catalyst, enabling the science to be effectively applied to the forecasting of storms and weather.

The settlement of the continent, gradually pushing the frontier westward, widened the field of observation. The Civil War marks an important turning point, from financial stringency to post-war inflation, which accounts for the diffusion of meteorological work among many institutions where it was scantily supported by eking out small sums from budgets intended for other purposes, before the war, and then afterward the quick development of a single relatively lavishly supplied institution.

Sir Napier Shaw (**68**, p. 1) argues that the change from horseback and stage coach to railways and from sailing vessels to steamers, as well as improvements in dwellings and clothing, caused people to lose interest in weather and to relegate it to institutions. On the other hand, is it not true that the size of atmospheric phenomena bars them from the scope of individuals, and even of institutions, like universities, that lack country-wide extent?

1753: In colonial times the only country-wide organization was the Post Office. Benjamin Franklin, appointed Postmaster-General of the Colonies, 1753, used his contacts with postmasters and shipmasters for research on progression of cyclones, and ocean currents (**47**, pp. 488–490), but his manner of publication nearly cost him all credit (**58**).

On April 2, 1814, amidst the war of 1812, James Tilton (1745–1822), revolutionary patriot, member of the Continental Congress, then Physician and Surgeon-General of the Army, directed hospital surgeons to record the weather (**49j**), (**1**). This was forgotten in the larger development of meteorological work that followed reorganization of the Army, April 14, 1818, by Secretary of War Calhoun, for whom the credit was claimed (**27**). The several chiefs of the Army Medical Department, who directed its meteorological service, were (**57**):

1813–1815. James Tilton, M. D. Physician and Surgeon-General.

1818–1836. Joseph Lovell, M. D., Surgeon-General.

1836–1861. Col. Thomas Lawson, M. D., Surgeon-General.

1861–1862. Col. C. A. Finley, M. D., Surgeon-General.

1862–1864. Brig. Gen. W. A. Hammond, M. D., Surgeon-General.

1864–1882. Brig. Gen. J. K. Barnes, M. D., Surgeon-General.

The Army Medical observations are especially valuable because they are the earliest available in the West. Long series of records were kept at a few fixed stations, but many posts were occupied for only a few years until the advance of the frontier carried them westward again. The meteorological organization terminated June 19, 1874, after which post surgeons sent their meteorological reports direct to the Signal Service and Weather Bureau. The results were published in four volumes (**2**), (**8**), (**21**), (**22**), and these were the basis of the climatologies of Forry (**12**) and Blodget (**25**).

The Surgeon-General's office cooperated with Espy's service, with the Smithsonian even to changing instruments and hours of observation (**16**, 1849, p. 14), with Paine in starting the meteorological work of the Signal Service (**32**), and with Myer in organizing that work (**33**, 1870).

1817: Josiah Meigs (1757–1822), Commissioner of the General Land Office, Interior Department (previously lawyer in Bermuda defending American vessels captured by privateers, professor of natural philosophy at Yale, acting president University of Georgia), asked money from Congress to equip land offices with barometers, etc. (**46**), (**49g**). Denied this aid, his bureau undertook a modest program of observations. The results, deposited with Meigs' papers in the American Institute of New York City, were placed in the New York Public Library, October, 1928.

1817: Heinrich Wilhelm Brandes (1777–1834), German meteorologist and mathematician, drew weather maps, invented isobars (1820), (isotherms had already been invented by Humboldt (**68**, pp. 260–261, 298)), discovered cyclonic wind circulation, rediscovered progression of cyclones, and proposed a meteorological service for the study of storms (**59** pp. 45–51), (**68**, p. 299), thus antedating many later claimants for these honors.

1825: Simeon DeWitt (1756–1834), Vice Chancellor of the University of the State of New York, previously Chief Topographic Engineer on Staff of General Washington in Revolution, also Surveyor General of New York, procured a grant from the state legislature, and organized meteorological observations at the Academies operated throughout the state by the Regents. Results were published in two volumes (**23**), (**36**), design and exposure of instruments studied. Joseph Henry (**39**), (**52c**) and James H. Coffin (**52a**) were trained in the New York service. Cooperated with Smithsonian from 1849 (**16**, 1849, p. 14). Appropriations ceased, 1863, and service mostly discontinued, on account of the Civil War.

1828: Heinrich Wilhelm Dove (1803–1879) and William C. Redfield (1789–1857) started debate on theory of tropical cyclones that afterward involved Espy and Loomis and led to important advances (**44**), (**68**, p. 296).

1834: James Pollard Espy (1785–1860), (**52b**), chairman of a joint committee of the American Philosophical Society and the Franklin Institute, of Philadelphia, established a net of observation stations to study storms. Four reports (**3**), (**31**) and numerous climatic tables were published. A weather map of the storm of June 19, 1836, in third report, based on observations at 18 stations scattered from Massachusetts to Ohio, shows the storm by wind directions only. The storm of March 16, 17, 18, 1838, in the fourth report, represented by a weather map based on observations at 50 stations covering the states east of the Mississippi, is shown by wind arrows, weather, and barometer readings, entered at each station, and by circles drawn around the centers of lowest pressure, at 12-hour intervals.

The committee obtained an appropriation of $4,000 from the Pennsylvania legislature (Laws of Pennsylvania, 1837, p. 73) to equip an observer in each county with barometer, thermometers, and rain gage. This quota of one observer per county, set up in 1837 as a goal to be attained, now stands as a limit that it is prohibited to exceed, act of August 30, 1890 (26 Stat. 371, 398.)

April 20, 1838; The first appearance of meteorology in the records of Congress is a memorial from the Pennsylvania Lyceum, instigated by Espy's committee, asking a national weather service (**4**).

December 18, 1838, Espy himself asked the Senate to offer awards in proportion to the result for rainmaking by burning woodlands (**5**).

December 20, 1839, the American Philosophical Society transmitted the request of the Royal Society, London, for cooperation with James Clark Ross's Antarctic Expedition by establishing five meteorological and magnetic observatories (**6**). John Quincy Adams (37, v. 10, pp. 211, 306), to whose committee this was referred, tried to attach these abservatories to the survey of the northeastern boundary, but was voted down (**7**). Philadelphians supplied one observatory, at Girard College, with aid from the Topographical Engineers, United States Army (**17**).

1840: Elias Loomis (1811–1889), professor of mathematics and natural philosophy, Western Reserve College, Hudson, Ohio, published an important paper on storms (**9**) in which progressive movement was shown by mapping the trough line on successive days, a method afterward adhered to by Espy (**16** 1859, pp. 108–111). A second paper (**13**) shows the storm by isobars and isotherms, essentially as in present-day weather maps. Inasmuch as Brandes described but did not publish his isobaric maps of 1820, Loomis is entitled to great credit (**45**), (**59**), (**68**).

1840: Espy visited England and France to present memoirs to the British Association for the Advancement of Science and the French Academy of Sciences (**10**), where Arago, in his speech of introduction, bracketed Espy with Ampere and Newton.

1841: Espy's Philosophy of Storms (**11**) published, bringing convection and thermodynamics of moist air into meteorological science with their proper weight.

January 6, 1842: Espy appeared in Washington, determined to make a place for himself as national meteorologist. J. A. Adams, chairman of the Congressional committee on the Smithson bequest, records the interview in which Espy sought to have that bequest devoted to a national weather service with Espy as chief (**37**, v. 10, p. 65, v. 11, p. 52). Espy approached other influential politicians and secured a place as Professor of Mathematics, Depot of Charts, Navy Department (the germ of the present Naval Observatory and Hydrographic Office) which he held from May 7, 1842 to July 5, 1845, and another as clerk at $2,000 per annum in the Surgeon General's office beginning August 26, 1842. The item of $3,000 for meteorological work inserted by Senator Preston, of South Carolina, in the Army Bill (Act of August 23, 1842) had not created a position, hence Espy was soon attacked by watchdogs of the Treasury (**56**), pp. 507–511, but Espy enlisted powerful friends, including John Q. Adams, Jefferson Davis, Alexander H. Stephens (**40**), (**61**, p. 45), (**33**, 1883, pp. 586–588), whose tactics of inserting a rider in one appropriation bill after another, Army, Civil and Diplomatic, Naval, Legislative, Executive and Judicial, sufficed to afford him a salary of $2,000 every year until June 30, 1859 (**56**, p. 608), although Senator Pearce, of Maryland, was obliged to threaten a filibuster in the closing hours of the session to get it through on one occasion, and it was forgotten and the fiscal year 1847–48 not covered until 1852. Espy also applied his knowledge of air currents to the invention of a ventilator, which the Twenty-ninth Congress had him install on the chambers of both houses at not to exceed $250 each, and a relief bill to pay him $10,000 for the use of his ventilators on naval vessels appeared session after session.

Espy expanded the observing net that he had organized at Philadelphia in 1834 to a corps of 110 in 1842 and 1843, 50 having barometers. Increase A. Lapham became Espy's observer at Milwaukee, and his papers show daily observations tabulated on printed forms, mailed at the end of each month. These were addressed to the Surgeon General's office until August, 1849, afterward to the Navy Department. The printed forms of the Smithsonian were used beginning 1853. Espy and assistant, paid from his $2,000, extracted data, plotted them on daily weather maps, and returned the reports to the observers. Selected maps, graphs of the march of the barometer, and generalizations of the laws of storms, afforded material for four reports (**14**), (**20**), (**26**), the last of which had the distinction of being submitted to Congress as a Presidential message.

Espy and Henry had been fellow members of the American Philosophical Society at Philadelphia and came into close relations after Henry came to Washington as Secretary of the Smithsonian Institution in 1846. Espy and Loomis wrote letters in support of the meteorological part of Henry's program for the Institution (**18**); Espy signed with Henry a joint circular soliciting observers (**16**, 1851, p. 68); Espy enjoyed laboratory facilities at the Smithsonian (**26**). On the other hand, Henry procured an order from the Secretary of the Navy directing Espy to cooperate with the Smithsonian (**16**, 1848, p. 29) and claims that Espy was directed to apply to him for instructions (**16**, 1849, p. 14), and he was much interested in Espy's appropriation (**16**, 1849, p. 14), (**56**). However, the tenor of Espy's reports and of Bache's eulogy on Espy (**16**, 1859, p. 108–111) indicate that Espy attached little importance to such restrictions. The claim of Assistant Secretary Goode that "the memoirs of Professor James P. Espy on meteorology * * * were all prepared as part of the Smithsonian meteorological work" (**54**, p. 496) is discounted by the reports themselves. The first report was published and the material of the second and third, was gathered before the Smithsonian was organized. Espy's generalizations supplied one of the arguments for the memorial of Lapham (**32**) that finally resulted in the establishment of a national weather service 10 years after Espy's death.

July 1, 1842, Matthew Fontaine Maury (1806–1873) was assigned to charge of the Depot of Charts (Depot of Charts, 1830–1844; Naval or National Observatory,

1844–1854; Naval Observatory and Hydrographic Office, 1854–1866; Hydrographic Office separated, 1866) (**49b**), and began to collect and summarize ship's log-books, "Wind and Current Charts," published beginning 1846; organized International Marine Meteorological Conference, Brussels, 1853; published "Physical Geography of the Sea," first edition, 1854, fifteenth, 1874; proposed to collect weather observations from farmers as he had from sailors, and Senator Harlan introduced a bill to enable him to do so, 1856 (**24**). Maury's wind and current charts enabled merchant sailing vessels to shorten voyages and were highly appreciated by merchants and underwriters. Those of New York City presented him a $5,000 silver service, 1853, and foreign potentates showered upon him medals and orders of nobility. He was elected to 45 learned societies, 20 foreign. He was not appreciated by his superior officials, who sought to retire him. He resigned, 1861, to throw in his lot with the Confederacy (**43**), (**69**), (**70**), (**71**).

1844. Morse and Vail demonstrated electric telegraph (**52e**), Washington-Baltimore, and established first commercial line, 1845.

1846. Redfield suggested telegraph for storm warnings, (**15**).

1847. First storm warnings, Barbadoes, Carlisle Bay from barometer at Bridgetown (**68**, p. 297).

1846: Smithsonian Institution (**49h, 54, 56**) organized under executive direction of Joseph Henry (1799–1878) (**39**), pioneer physicist, whose name is now borne by the unit of magnetic induction. He had been in contact with the meteorological work in New York and at Philadelphia (**56**, pp. 212, 257–263). His program for the new Smithsonian Institution (**16**, 1847, pp. 6, 13) contemplated climatological observations and telegraphic reports for prediction of weather and storms, but was greatly hampered by meager funds. The Regents appropriated $1,000 for meteorological work at the end of 1848, and a corps of 150 observers was organized and began reporting 1849. Their number increased, and they were augmented as Henry procured the cooperation of the Surgeon General's hospital surgeons, Espy's observers in the Navy Department, the New York Academy observers, and of observers at grammar schools and light houses in Canada. Henry stimulated the beginning of state weather services in Massachusetts (1849), Maine, Illinois (1855), Texas (1858). The number of observers rose to 616 just before the Civil War, and reached 599 again in 1869. Suspension of payments by the First National Bank of Washington, in the panic of 1873, tied up the working funds of the Smithsonian and compelled Henry to ask the Signal Service to take over the Smithsonian observers, and this was done February 2, 1874 (**33**, 1874, pp. 88–89, 286–287).

Henry cooperated with the Commissioner of Patents, then in charge of government work in agriculture, prepared reports on the relations of meteorology to agriculture in exchange for the franking of observers' reports and the publication of observations at Government expense (**16**, 1855 pp. 26–28), (**30**). The title of the latter publication is misleading in suggesting that observations were made under the direction of the Patent Office. This cooperation suddenly ceased at the death of Patent Commissioner Mason, 1860, (**16**, 1850, p. 34), but on creation of the office of Commissioner of Agriculture, 1862, similar relations were established (**16**, 1863, p. 32). Results were published (**30**), (**35**). Lorin Blodget, climatologist, was employed to prepare the first (**16**, 1854, p. 25), but "set up such claims to a personal right of property in it" (**16**, 1855 p. 19) that it was taken away and given to Prof. J. H. Coffin, of La Fayette College (**52a**), who, followed by his son, performed many valuable services for the Smithsonian and for meteorology. The later volumes were prepared by C. A. Schott, of the Coast and Geodetic Survey.

1848: Jones & Co. (John D. Jones, agent, later vice president, and president to 1895, Atlantic Mutual Insurance Co., marine underwriters), Merchants Exchange, New York City, advertised "daily and hourly telegraphic meteorological reports" (**19**). Compare Francis Galton's Weather Map Company (**68**, pp. 306–308).

June 14, 1849: James Glaisher started first telegraphic weather reports for London Daily News (**68**, p. 302).

August 8, to October 11, 1851: Telegraphic weather maps lithographed and sold at a penny each, at the Crystal Palace Exhibition, London (**59**, p. 64), (**68**, p. 302).

November 14, 1854: Storm in Black Sea, during Crimean War, enabled Leverrier, discoverer of the planet Neptune, to procure Emperor Napoleon's consent for first national telegraphic weather service, beginning February 17, 1855, in France; extended over Europe, 1857; published daily bulletin, 1858; issued storm warnings, 1860 (preceded by Buys Ballot in Holland by a few months); published daily isobaric weather maps from 1863 (**59**), (**68**).

1857: Smithsonian telegraphic weather observations, arranged with presidents of telegraph companies in 1849 (**16**, 1850, p. 14), begun along lines New York to New Orleans and Washington to Cincinnati (**16**, 1857, pp. 26, 27). Weather reports published in "Evening Star" and exhibited to visitors to Smithsonian by hanging pieces of colored card on iron pins fixed in a map (**16**, 1858, p. 32); later these cards were cut into disks bearing arrows to show wind direction also, and were oriented by hanging from one of eight holes (**16**, 1869, p. 50). Compare this device with maps of Brandes, 1820, and Loomis, 1843.

Henry predicted weather for his own use in planning lectures and reported results to a scientific society (**28**), (**55**). These observations were crowded off the wires by war business in 1861, temporarily resumed 1862 (**16**, 1862), and contemplated again 1867 (**16**, 1867, p. 28.) Arrival of the French maps and beginning of weather services throughout Europe and in Turkey and India inspired Henry to urge in his annual reports (**16**, 1865, pp. 56–59) the establishment of an American national weather service. In spite of the presence of three senators and three representatives on the Board of Regents of the Smithsonian Institution, no action was taken to place Henry's recommendations before Congress (**56**).

The contributions of the Smithsonian to meteorology were listed by Henry (**16**, 1871, pp. 43, 57) as follows: Inaugurating the climatological observations which have been in operation upward of 20 years, introduction of improved instruments, publication of extensive series of meteorological tables, reducing and publishing material from all records since the first establishment of the country, showing the practicability of telegraphic weather signals, publishing Arctic observations, publishing special records, memoirs on meteorological subjects, diffusion of knowledge of meteorology through correspondence, urging upon Congress the establishment of a meteorological department.

1857: Capt. George Gordon Meade, Superintendent of the Survey of the North and Northwest Lakes, Corps of Topographical Engineers, United States Army, commander in chief of the Union army at the battle of Gettysburg, began meteorological observations at 25 stations on the Great Lakes. Results were published at Detroit and in reports of the Chief of Engineers (**29**), and manuscript

records forwarded to the Smithsonian. This service ceased 1872–1876 as the Signal Service extended over the same area.

September 1, 1869: Cleveland Abbe (1838–1916), director of the Cincinnati Astronomical Observatory, organized daily telegraphic reports from cities in the Middle West, and published a weather map with the support of the Cincinnati Chamber of Commerce for three months (**34**), afterward at Abbe's own expense for six months. Meantime, in February, 1870, Manager Armstrong of the Cincinnati office of the Western Union Telegraph Co., through whose hands Abbe's reports were received, started a similar publication, with which Abbe merged his efforts in May, 1870. This later publication, copies of which survive (**67**, p. 25) and in Lapham papers in Wisconsin Historical Society, exhibit the weather by discrete symbols and figures for weather, wind direction, and temperature, but no barometer readings, isobars, isotherms, nor weather predictions. Compare maps of Brandes, 1820, Loomis, 1843, and Paris Observatory, 1863. On July 20, 1869, Abbe and his friends organized a meteorological society, the Western Meteorological Association.

1869: Daniel Draper (1841–) organized the municipal meteorological observatory in Central Park, New York City, now operated by the United States Weather Bureau. Draper devised many automatic instruments for the observatory, which have also found use in industry.

1869, December 8: Increase A. Lapham (1811–1875), Quaker, philanthropist, naturalist, meteorological observer for Espy, Smithsonian Institution, Lake Survey, and Abbe, sent a memorial, "Disasters on the Lakes", (**32**), to Gen. Halbert E. Paine, Member of Congress from Lapham's home district at Milwaukee. This memorial enumerated the losses of sailors and ships on the Great Lakes in the storms of 1868 and 1869, cited Espy's laws of American storms, and Leverrier's successes in giving warning of European storms. This scientific, humanitarian, and economic appeal, the solidarity of Congress, then filled with Union officers accustomed to work together, contributed to Paine's success in procuring the passage of the Act of Congress, February 9, 1870 (16 Stat. 369), directing the Secretary of War to take meteorological observations and give warning of the approach of storms. On February 28, 1870, the Secretary of War assigned this duty to the Chief Signal Officer (**33**, 1870, p. 16), an office that originated June 27, 1860, when Asst. Surg. Albert J. Myer was appointed Major and Signal Officer to develop a system of military communication that he had invented (**51**). Although he had not held that office continuously, Myer was Chief Signal Officer in 1870 when the meteorological work was authorized by Congress, and Paine states (Lapham Papers) that Myer secured its assignment to his administration, where it was designated the "Division of telegrams and reports for the benefit of commerce." Sketches of the Signal Service (**41**), (**46**), (**52***a*) and of the Weather Bureau (**66**) are available, so that only a few points will be given here.

The initial appropriations for meteorological work by the Signal Service were: Year ending June 30, 1870, $15,000; 1871, $50,000; 1872, $102,451; 1873, $250,000. These figures do not include pay or allowances of officers and enlisted men. The total appropriation exceeded a million dollars in 1884 and 1885, and was mostly expended on meteorological work.

Observations commenced November 1, 1870. The first forecaster was Increase A. Lapham, "assistant to the Chief Signal Officer," stationed at Chicago, with supervision over the signal service on the Lakes until the close of navigation, 1870, who issued the first storm warning at noon, November 8, 1870. Lapham drew isobaric maps such as forecasters use to day (**33, 1871**, pp. 7, 167–172, and 15 charts).

In order to enlist state aid in distributing agricultural warnings and to collect agricultural and climatological observations, State Weather Services (**49 d, e, 50**) were organized from 1883 onward by Lieut. H. H. C. Dunwoody, who had suggested them in 1881 (**41**). In October 1895 control of these services passed from the states to the United States Weather Bureau, and with the "voluntary observers" of the Smithsonian net were then merged in the Climate and Crop (now Climatological) Service of the Weather Bureau.

Beginning about 1884, agitation for conversion of the meteorological service into a civilian bureau brought a series of bills before Congress. The Act of October 1, 1890 (26 Stat. 653), introduced by Senator William B. Bate, of Tennessee, effected the transfer to the Department of Agriculture. The magnitude of the change is best seen by comparing the expenditures of the Signal Corps before and after the change on June 30, 1891: 1891, $753,284.70; 1892, $31,697.62. The chiefs of the meteorological service, with dates of appointment have been:

July 28, 1866: Brig. Gen. Albert J. Myer (1828–1880).
December 15, 1880: Brig. Gen. William B. Hazen (1830–1887).
March 3, 1887: Brig. Gen. Adolphus W. Greely (1844–).
July 1, 1891: Mark W. Harrington (1848–1926).
July 4, 1895: Willis L. Moore (1856–1927).
August 4, 1913: Charles F. Marvin (1858–).

Published results are considerably too numerous to mention, but summaries of summaries will be found in Bulletins Q and W of the Weather Bureau and in the Atlas of American Agriculture. The publications of the Signal Service and of the Weather Bureau have been listed (**48**), (**63**).

1884–1896: The New England Meteorological Society, W. M. Davis, secretary, was organized to operate the state weather service as a unit for New England (**42**), (**53**). It also functioned as a scientific society, holding meetings, and by cooperative investigation of sea breeze, thunderstorms, etc. Meetings and papers were reported in the American Meteorological Journal, results in Publications of Harvard College Observatory.

1884: Abbott Lawrence Rotch (1861–1921) founded Blue Hill Meteorological Observatory, primarily for research on clouds, instruments, and upper air observations with kites and balloons, the latter extended, 1905, to the trade-wind region of the Atlantic in cooperation with Teisserenc de Bort. Rotch was active in support of the New England Meteorological Society and the American Meteorological Journal. Since 1912 the observatory, bequeathed to Harvard University has been directed by Alexander McAdie, former official of the United States Weather Bureau. Among Blue Hill meteorologists are H. H. Clayton, S. P. Fergusson, C. F. Brooks, A. H. Palmer (**62, 73**). Results published in Annals of Harvard College Observatory and Publications of Blue Hill Observatory.

1917: The World War brought into existence the Meteorological Section, Signal Corps, United States Army (**64**), and the Aerographic Section, United States Navy (**65**).

1919: The American Meteorological Society, C. F. Brooks, secretary, open to meteorologists throughout North and South America, was organized (**72**).

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Year	Cong. Doc. Ser.	No. of Doc.	Page
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1860	1079	1	253
1861	1118	1	95
1862–63	1184	--------	201, 491
1866	1285	1	414
1867	1325	1	--------
1868	1368	1	--------
1869	1413	1	--------

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SOIL TEMPERATURES IN THE UNITED STATES [1]

By EDITH M. FITTON and CHARLES F. BROOKS

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By writing to all the agricultural experiment stations and examining the available literature on the subject, soil

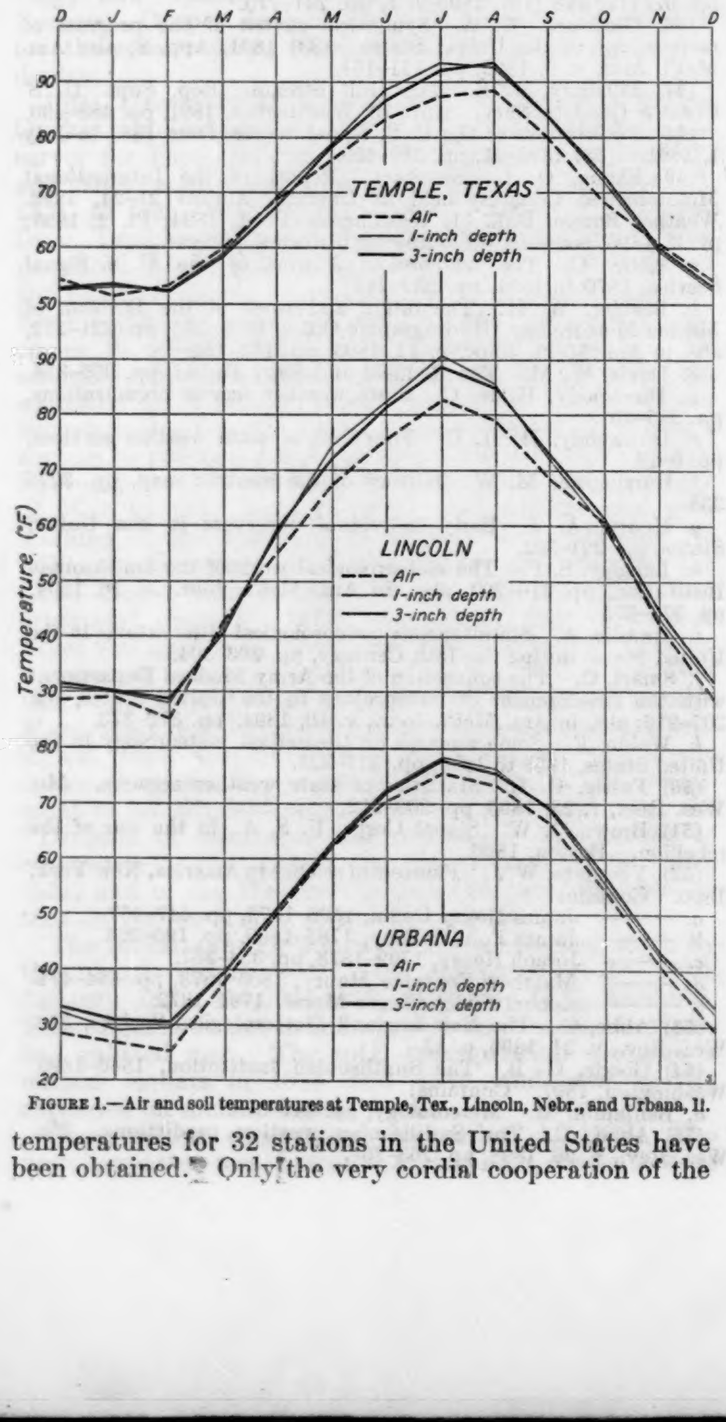

FIGURE 1.—Air and soil temperatures at Temple, Tex., Lincoln, Nebr., and Urbana, Ill.

temperatures for 32 stations in the United States have been obtained. Only the very cordial cooperation of the agricultural experiment stations, the library of the United States Weather Bureau, and certain individuals has made possible the collection of the data. The stations, though few in number, are fairly representative of the country as a whole.

Many variations in the conditions under which the soil temperatures were taken occur. In general, the experiment stations obtained soil temperatures not because of interest primarily in the temperatures themselves, but to determine the extent to which the temperatures were favorable or unfavorable for an important local crop or for bacteria harmful or helpful to that crop. Thus the thermometers were often placed at the depth at which the seed would be planted, so the depths for the different stations vary considerably. Also, because the interest was chiefly in connection with crops, records were often taken only during the growing season instead of throughout the year. Soils such as clay, loam, sand, peat, etc., are indicated; soil covers are various—bare, cultivated, sod, orchard, tobacco, cotton, mulches, etc.; exposures noted at different stations indicate variations between hillsides and bottom lands, dry soil and wet soil, shade and sun, etc. The accompanying table of soil temperatures indicates these variations where possible; it will be noted that some stations make no specification whatever as to the soil, soil cover, or exposure at the place where the soil thermometers were placed. In cases where temperatures of several kinds of soil or soil cover or exposure were recorded at one station, all of the data are included in the table for purposes of comparison at the station itself.

The material was sent to the authors in many different forms—some of it had already been published; some was in the form of graphs from which the desired temperatures could be read; in many instances the original thermograph records were sent and readings and tabulations were made from them; often a letter from an official of the station indicated all the soil temperatures that the station had available. Where possible, the temperatures in the tables were obtained by averaging the mean daily maximum and mean daily minimum temperatures for each month.

It is very apparent that the soil temperatures obtained for the 32 stations are by no means uniform—variations occur in the years, months, or days of record, the method

[1] Based on a paper presented before the Association of American Geographers at Worcester, Mass., December 29, 1930, by Edith M. Fitton.

of taking the record and of compiling tables from it, the kind of soil, depth, soil cover, and exposure. Hence the records at different stations are not strictly comparable with one another; however, the data are valuable for the individual stations, especially when temperatures for different depths, soils, and exposures are recorded at a single station. The scantiness of the material now available emphasizes the need for many additional observations of soil temperatures, which should be made under conditions as uniform as possible.

A study of the tabulated records now at hand and the graphs which illustrate them suggests a number of conclusions.

(*a*) Air and soil temperatures near the surface vary in a fairly parallel manner.

Since the temperature of the air is chiefly dependent on radiation and conduction from and to the ground, it follows that the diurnal and annual courses of the air temperatures and the ground temperatures should be quite similar. A number of stations provided air temperatures as well as soil temperatures. (See fig. 1 and the accompanying tables.)

(*b*) The soil temperatures at slight depths are generally higher than the air temperatures throughout the year. (Fig. 1.)

By day and especially in summer the ground is warmed to a much higher temperature than the air above it, so much so that, though it is cooled to a lower temperature at night, the mean temperature of the ground remains higher than that of the air. At Urbana, Ill., "the average monthly temperature of the soil to a depth of 1 to 3 inches is always higher than that of the air above it" (**14**, p. 42), but at Lincoln Nebr., (**21**) and at Temple, Tex., this statement does not hold true in the spring and fall. In the spring the reason is perhaps that it takes longer for the soil, continually cooled by conduction from below to warm up; in the fall, with shorter days and a longer period of nocturnal radiation, the soil cools more rapidly, though, as the winter months show, not to as great a degree as the air. Because of intense surface heating, the summer months show the widest variation between the air and soil temperatures, the soil at the 1-inch depth being considerably warmer than at 3 inches, with the interesting exception of August at Temple, Tex. The explanation for the exception probably lies in the fact that the deeper soil has become thoroughly warmed during the long summer of this southern station, and, since it retains its warmth at night better than the surface soil, its temperature shows a higher monthly average.

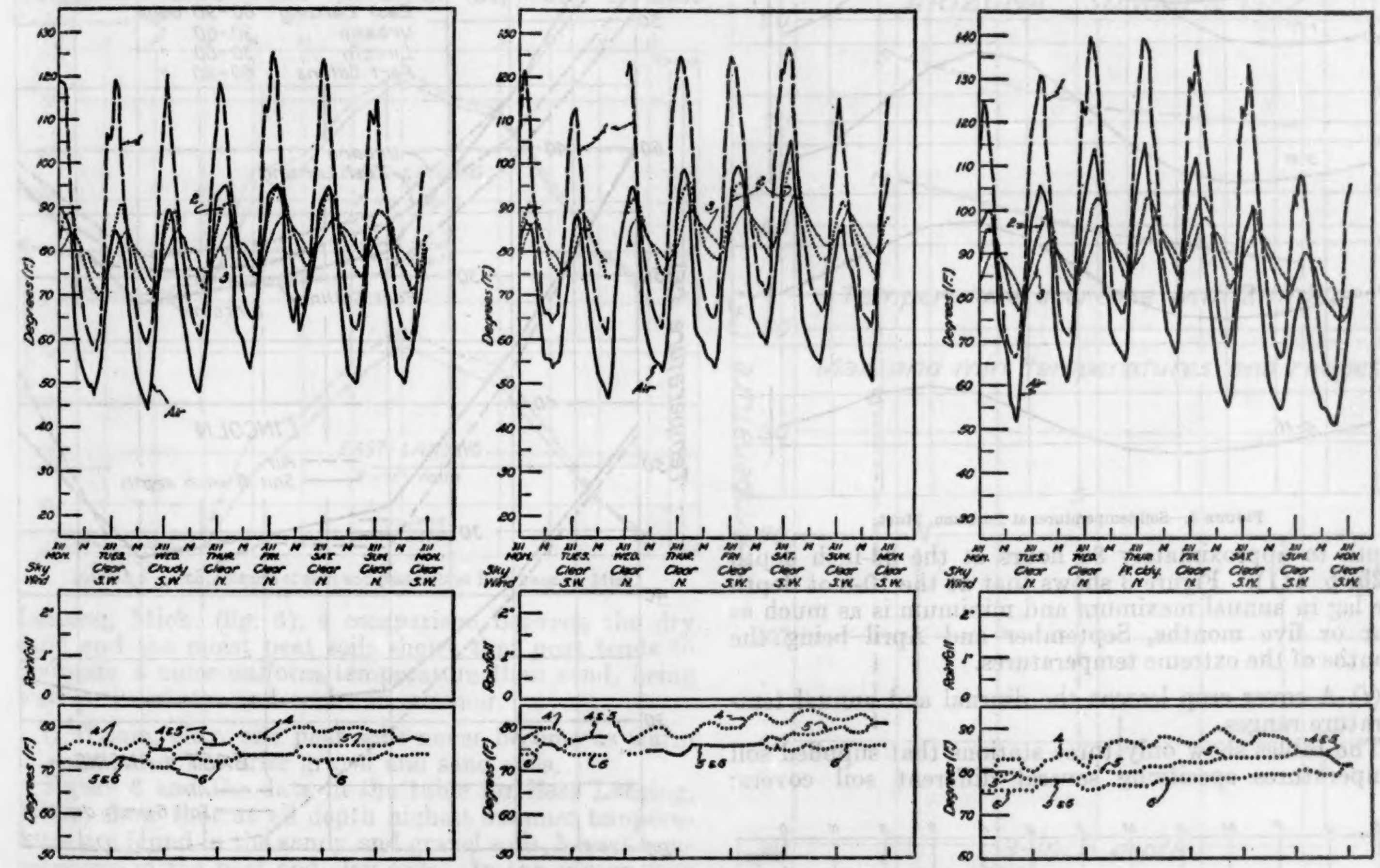

FIGURE 2.—Weekly courses of soil temperatures at different depths at Davis, Calif.

(*c*) The diurnal range in soil temperatures extends to a depth of about 3 feet (**60**, p. 79).

A study of the original thermograms which were sent by a number of stations showed this to be a fact, as does also Figure 2, from a soil paper by Alfred Smith published in Hilgardia (**32, a**, p. 91). The 36-inch-depth line is seen to have the least fluctuation during the weeks shown.

(*d*) The annual range in soil temperature is quite apparent at a depth of 10 feet, the greatest depth for which a record is obtainable in the United States.

Bozeman, Mont. (fig. 3) furnished soil temperatures to a depth of 10 feet. Here the annual range is still reasonably apparent and it probably extends to a depth of 30 or 40 feet (**60**, p. 80). Where the temperature line for the 10-foot depth is superimposed on the 1-foot temperature line, the greatly decreased annual range with

depth is at once apparent. The increase in uniformity of temperature with increase in depth, progressively indicated from top to bottom of Figure 3, is due to the fact that in the summer time with increasing depth the soil becomes colder; in the wintertime, with increasing depth, the soil becomes warmer.

(*e*) The lag of maximum and minimum soil temperatures increases with depth.

According to Alfred Smith's experiments at Davis, Calif., the lag "varies from less than 1 hour at the ½-inch

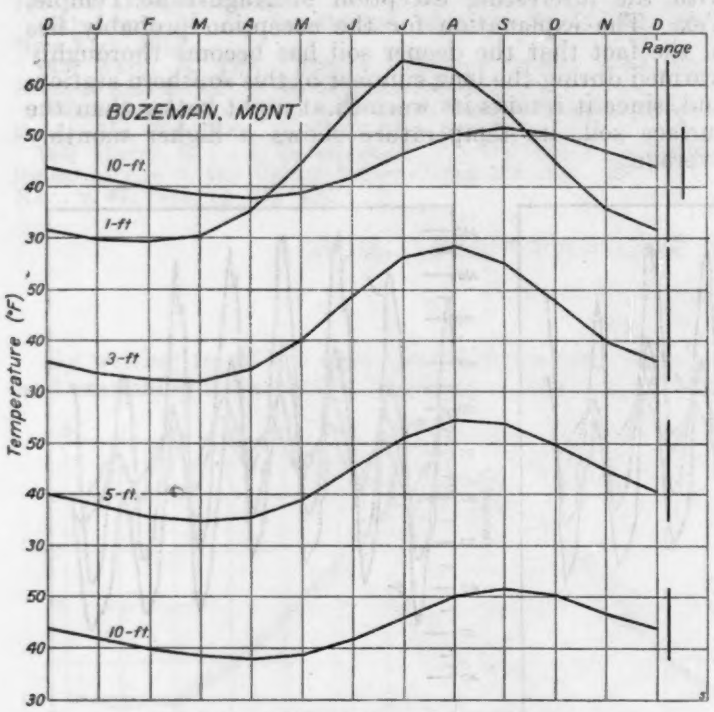

FIGURE 3.—Soil temperatures at Bozeman, Mont.

depth to approximately 80 hours at the 36-inch depth (**32b**, p. 111). Figure 3 shows that at the 10-foot depth the lag in annual maximum and minimum is as much as four or five months, September and April being the months of the extreme temperatures.

(*f*) A cover crop lessens the diurnal and annual temperature ranges.

The tables show only three stations that supplied soil temperatures specifying several different soil covers;

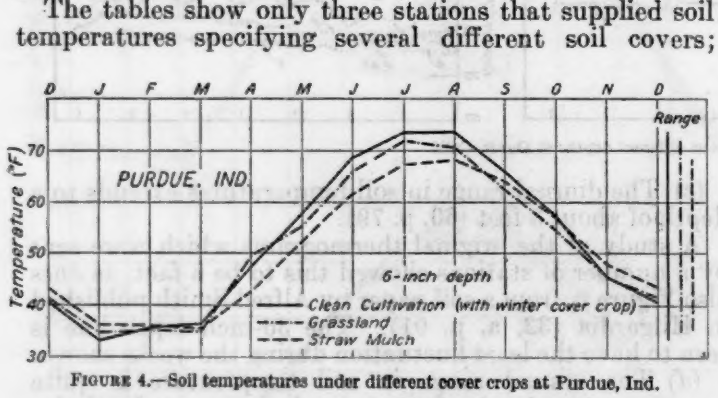

FIGURE 4.—Soil temperatures under different cover crops at Purdue, Ind.

the data for Purdue, Ind., are shown in Figure 4. The mean annual range under straw mulch is least; under clean clutivation it is greatest. The spring and summer months show the greatest differences in temperature between the soil under clean cultivation and that under straw mulch, because the bare ground warms up so much more rapidly as well as to a greater degree than the ground under straw.

(*g*) In the winter time, northerly stations where the snow cover is more or less permanent show higher mean monthly soil temperatures than stations somewhat farther south or west but lacking a good snow cover.

By means of Figure 5, the winter air and soil temperatures at East Lansing and Lincoln (**21**) may be compared. While the air temperatures at East Lansing average 5° F. or more below those at Lincoln, the soil temperatures are several degrees higher than those at Lincoln. The explanation seems to lie in the fact that a snow cover of fairly permanent duration maintains the soil temperatures at about 32° regardless of the air temperature, whereas

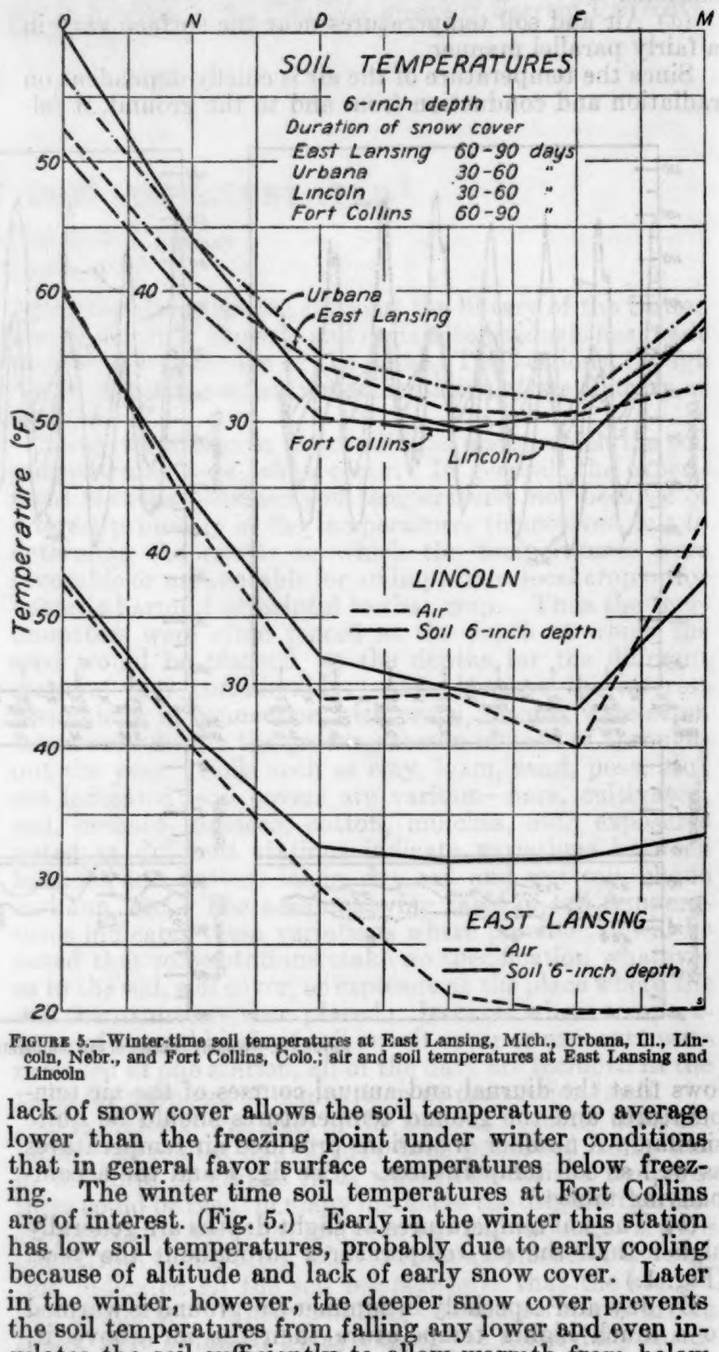

FIGURE 5.—Winter-time soil temperatures at East Lansing, Mich., Urbana, Ill., Lincoln, Nebr., and Fort Collins, Colo.; air and soil temperatures at East Lansing and Lincoln

lack of snow cover allows the soil temperature to average lower than the freezing point under winter conditions that in general favor surface temperatures below freezing. The winter time soil temperatures at Fort Collins are of interest. (Fig. 5.) Early in the winter this station has low soil temperatures, probably due to early cooling because of altitude and lack of early snow cover. Later in the winter, however, the deeper snow cover prevents the soil temperatures from falling any lower and even insulates the soil sufficiently to allow warmth from below to cause a slight rise in soil temperature.

A uniformity of temperature throughout the winter months which is probably maintained by the snow cover is apparent in most of the illustrations.

(*h*) The presence of moisture in the soil tends to give a low and uniform temperature.

Auburn, Ala., Columbia, Mo., and Corvallis, Oreg., have furnished soil temperatures specifying whether the soil is wet or dry. At Auburn the wet bottom-land soil seems to be warmer than the dry hilltop soil, but this may be merely the result of the method of obtaining the means by averaging the maximum and minimum temperatures, for the minimum temperatures on the wet ground are several degrees higher than on the dry sandy ground. At Columbia the "seepy spot" on the slope is generally cooler by about 1° than the other two exposures, both at the 12-inch and 36-inch depths. In 3 instances out of a possible 24 comparisons the seepy spot was found to be warmer than the other exposures.

At Corvallis the difference is between irrigated and unirrigated soils. The conclusion is that "the presence of irrigation water and the resulting evaporation tends to give a low uniform temperature, but the difference due to irrigation would decrease with depth" (**31**, p. 30). At East

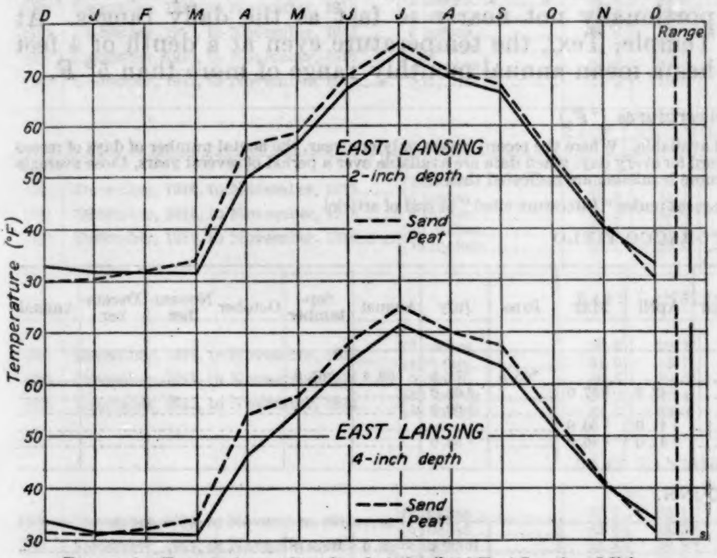

FIGURE 6.—Temperatures of sand and peat soils at East Lansing, Mich.

Lansing, Mich. (fig. 6), a comparison between the dry sand and the moist peat soils shows that peat tends to maintain a more uniform temperature than sand, being warmer in winter and cooler in summer.

(*i*) Loam, clay, and peat soils never become as warm in summer as the drier gravel and sand soils.

Figure 6 and the data in the table for East Lansing, Mich., show that at all depth highest summer temperatures are found in the sandy and gravel soils, lowest temperatures in the peat and clay soils. In the winter time all of the soils tend to be at a temperature of about 32° F. when under a snow cover.

(*j*) Soil temperature and its annual range decreases with altitude.

The upper portion of Figure 7 shows the decrease of temperature with increasing altitude for both north and south slopes. The lower portion of the figure shows the lessening range with increase in altitude.

(*k*) South exposures at any altitude have higher temperatures and a greater range than north exposures.

The lower portion of Figure 7 shows this graphically. It is of interest to note how much less rapidly the maximum temperatures on the south slope decrease with altitude than the maximum temperatures on the north slope. The mean temperatures for the south exposures averages 12° F. or more above those for the north exposures at the same levels, and even at 9,000 feet the mean for the south exposure is still almost 5° higher than the mean for the north exposure at only 7,000 feet.

Daily and monthly ranges, shown in Tables 2 and 3 for certain stations, provide further quantitative comparisons of soil temperature characteristics at different depths at the several seasons and in various climates. Daily ranges are greatest nearest the surface. The 1922–1925 series at Fargo, N. Dak. (**18**), described as an unusually warm period, had a daily range at 1-inch depth in excess of the range of air temperature a few feet above the ground. The other Fargo series (**19**), however, at ½-inch depth showed a range only one-fourth to one-third as great as that at 1

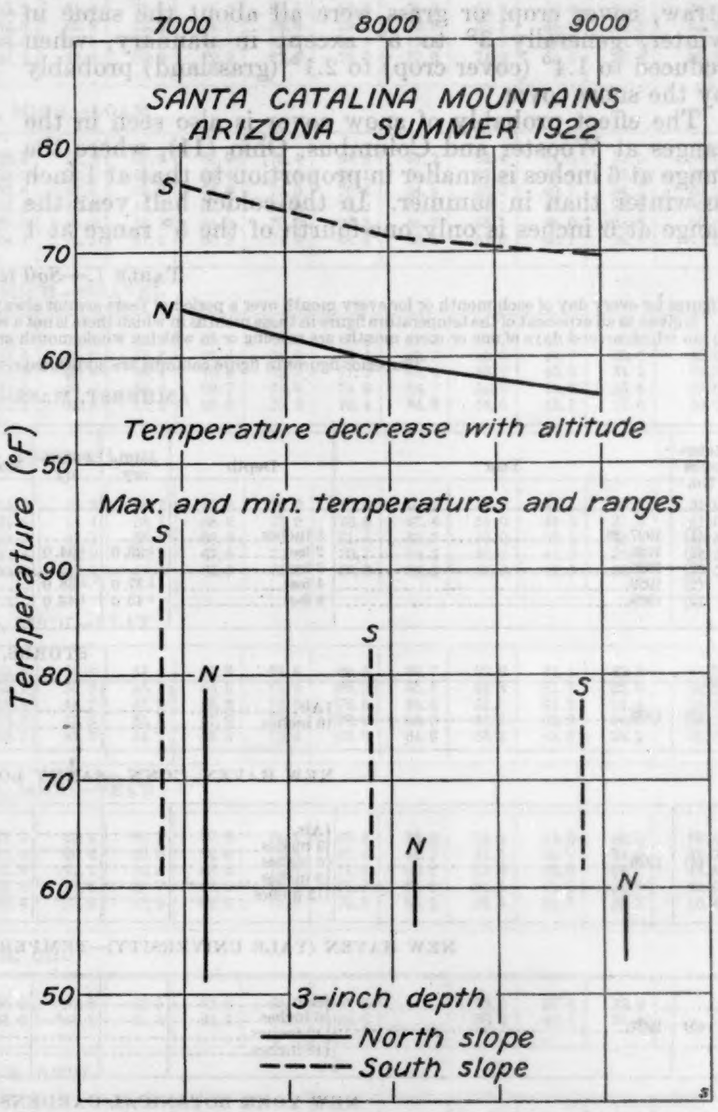

FIGURE 7.—Mean, maximum, and minimum temperatures at different altitudes on the north and south sides of the Santa Catalina Mountains, Ariz.

inch in the first series. In general (Table 2), the range of soil temperature at the 3-inch depth was about three-fourths the range of air temperature in the warmer half year and less than two-thirds of the reduced air temperature range in the colder half year.

From this general surface layer downward the daily range decreases geometrically. In the most complete New Haven series (**4**) the daily range decreases by about half for each 3-inch increase in depth, becoming at 12 inches only one-fifth to one-tenth that at 3 inches. In the other New Haven series (**5**), the range at 6 inches is about the same as in the first, but that at 12 inches is still nearly as large, and the range at 18 inches is much like

that at half the depth in the first series. As these observations were made in borings, a more rapid exchange of heat than usually occurs in the ground may have taken place in these holes. In the New York Botanical Gardens daily ranges at a depth of 1 foot in clay soil mixed with loam were about the same as at the same depth in the first New Haven series, namely 1° to 2(+)° F.

Any covering on the soil reduces the daily range markedly. In the Purdue experiment (**13**) ranges at 6 inches under straw were only 2.5° to 5° F., while those under clean cultivation were 8° to 12° F. in the warmer half year. Ranges under grassland were nearly as large as those under clean cultivation, however. Ranges under straw, cover crop, or grass were all about the same in winter, generally 3° to 5° except in January, when reduced to 1.4° (cover crop) to 2.1° (grassland) probably by the snow cover.

The effect probably of snow cover is also seen in the ranges at Wooster and Columbus, Ohio (**11**), where the range at 6 inches is smaller in proportion to that at 1 inch in winter than in summer. In the colder half year the range at 6 inches is only one-fourth of the 5° range at 1 inch, while in the warmer half year the range at 6 inches is one-third of the 20+° range at 1 inch. In general there are much smaller daily ranges at slight depths in winter than in summer, though the range of air temperature is not changed so much. The air temperature range decreases by a third, while that of the soil decreases by a half to three-quarters or more. At a depth of 18 inches, for which depth we have ranges through the year only at Lexington, Ky. (**12**), the diurnal range becomes about the same small value, 1° F., in all months.

The drier climates, so far as these samples go, have the larger daily ranges of soil temperature. Also the drier months in the warm season have the larger ranges. The ranges at Fargo, N. Dak. (**18** and **19**), increased markedly toward late summer as the normal convectional rainfall decreased.

Monthly ranges (Table 3) are considerable to depths of 12 inches in the north and 24 inches in the south. They decrease fairly rapidly with increase of depth, but proportionally not nearly so fast as the daily ranges. At Temple, Tex., the temperature even at a depth of 4 feet has a mean annual monthly range of more than 5° F.

TABLE 1.—*Soil temperatures (°F.)*

Figures for every day of each month or for every month over a period of years are not always available. Where the record covers only one year, the acutal number of days of record is given as an exponent of the temperature figure in those months in which there is not a record for every day; when data are available over a period of several years, those averages in which several days of one or more months are missing or in which a whole month or more is missing are indicated thus (*)

[Superior figures in figure columns are additional references under "Literature cited" at end of article]

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
						AMHERST, MASS.—TOBACCO FIELD									
(1)	1927–28	5 inches						*65.5	*71.8	69.4	*67.6				
(2)	1929	2 feet	[1] 36.0	[1] 34.0		[1] 43.0	[1] 57.0		[3] 69.0						
(2)	1929	3 feet							[3] 60.0						
(2)	1929	4 feet	[1] 37.0	[1] 38.0		[1] 41.0	[1] 50.0								
(2)	1929	8 feet	[1] 45.0	[1] 42.0		[1] 41.0	[1] 46.0		[3] 55.0						
						STORRS, CONN.									
(3)	1922	Air							[18] 68.8	[27] 66.9	[12] 65.0				
		6 inches							[18] 73.0	[30] 70.6	[13] 66.2				
						NEW HAVEN, CONN.—SANDY LOAM, LEVEL, EXPOSED TO SUN									
(4)	1926	Air					[21] 65.2	70.0	77.0	75.8	67.4	56.0	[24] 47.3		
		3 inches					[8] 60.7	[29] 68.4	81.2	[30] 74.9	[28] 67.0	54.4	[19] 46.1		
		6 inches					[8] 66.3	[29] 65.7	74.8	[30] 73.1	[27] 65.9	54.5	[17] 47.0		
		9 inches					[8] 58.6	65.0	72.4	[30] 72.4	[28] 66.1	54.8	[19] 46.8		
		12 inches					[9] 56.1	[29] 63.4	71.2	[30] 71.2	[28] 65.2	[30] 55.2	[18] 48.2		
						NEW HAVEN (YALE UNIVERSITY)—TEMPERATURES TAKEN IN BORINGS IN THE SOIL									
(5)	1924	Air				45.0	53.2								
		6 inches				44.2	54.2								
		12 inches				43.5	52.6								
		18 inches				43.2	51.6								
						NEW YORK BOTANICAL GARDENS—CLAY SOIL MIXED WITH LOAM									
(6)	1902	Air						[22] 63.9	70.2	68.2	61.9	[23] 53.4	[23] 46.6	[16] 31.3	
		12 inches						[21] 48.2	51.6	[30] 48.2	43.5	35.8	29.5	[21] 29.7	
						BLACKSBURG, VA.—HAGERSTOWN SILT LOAM IN AN ORCHARD									
(7)	1915	Air							70.2	68.2					
		3 inches							76.4	74.3	Sod.				
		24 inches							70.0	71.2	Do.				
		3 inches							75.8	75.0	Partially cultivated.				
		24 inches							69.3	69.9	Do.				
		3 inches							76.1	76.0	Intensely cultivated.				
		24 inches							69.4	70.5	Do.				
						ATHENS, GA.—LAND BEDDED UP FOR COTTON									
(8)	1926	Air					68.3	Average from Apr. 22 to May 20.							
		1.5 inches					68.4	Do.							

TABLE 1.—*Soil temperatures* (°F.)—Continued

AUBURN, ALA.—SANDY SOIL ON A HILL, FREQUENTLY CULTIVATED DURING CROPS

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(9)	1889	Air	46.9	46.3	54.7	62.5	70.1	76.1	80.7	77.6	74.8	62.3	53.1	57.8	63.6
		3 inches	48.5	50.5	55.2	65.5	72.2	74.0	86.5	82.2	75.5	64.8	52.2	52.0	64.9
		6 inches	48.2	55.5	53.8	64.8	72.0	73.5	85.8	81.5	75.0	65.2	52.8	51.2	64.9
		24 inches	49.5	50.5	53.8	62.5	70.5	74.2	81.5	80.0	80.8	68.2	58.8	55.0	65.4
		48 inches	52.5	50.5	53.5	59.8	67.2	72.2	77.0	78.0	79.8	70.8	63.5	58.5	65.3
		96 inches	58.0	55.5	55.2	57.2	61.2	67.2	71.0	73.2	75.0	72.5	77.0	63.5	65.5

AUBURN, ALA.—BOTTOM LAND ON THE BANK OF A SMALL STREAM

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(9)	1889	3 inches	48.0	51.0	55.2	64.0	73.8	75.0	87.5	83.2	76.2	64.8	52.8	51.8	65.3
		6 inches	48.8	51.5	55.2	65.8	73.5	74.5	86.8	83.0	76.0	65.5	53.0	50.5	65.3
		24 inches	51.2	51.8	54.5	63.0	70.5	74.8	81.2	80.2	77.5	68.8	59.2	55.0	65.6
		48 inches	53.5	52.2	54.2	60.5	67.2	72.2	77.0	78.0	77.0	71.2	63.5	59.0	65.5

EAST LANSING, MICH.—LOAM

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(10)	December, 1914, to November, 1915	2 inches	31.3	31.5	33.3	55.2	57.0	67.9	73.4	68.5	67.2	53.4	41.0	32.5	51.0
		4 inches	32.0	32.1	33.9	53.0	56.4	66.4	72.8	68.1	65.9	52.8	41.4	33.6	50.7
(10)	December, 1911, to November, 1915	6 inches	30.8	30.4	32.6	45.4	57.0	68.9	74.0	70.6	64.8	52.6	40.7	34.2	50.2
(10)	December, 1911, to November, 1914	12 inches	32.7	31.7	32.5	42.0	55.5	67.6	73.0	70.9	65.1	54.1	42.4	36.7	50.4
		18 inches	34.5	33.1	33.1	40.8	53.1	64.3	70.2	69.3	64.5	55.1	44.0	38.6	50.0
(10)	December, 1911, to November, 1915	Air	21.2	19.8	30.1	48.1	57.1	66.3	71.4	68.5	63.4	52.6	40.1	29.4	47.3

EAST LANSING, MICH.—GRAVEL

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(10)	December, 1914, to November, 1915	2 inches	31.8	32.2	34.3	56.2	58.5	69.8	75.7	70.5	67.7	53.7	41.4	32.3	52.0
		4 inches	32.3	32.7	34.4	54.8	57.8	67.9	74.2	69.4	66.7	53.6	41.7	33.0	51.5
(10)	December, 1911, to November, 1915	6 inches	31.2	31.0	33.6	47.6	58.4	70.4	75.0	71.5	65.4	53.2	40.9	34.2	51.0
(10)	December, 1911, to November, 1914	12 inches	32.1	31.4	33.5	44.0	56.6	68.7	73.6	71.0	64.7	53.6	41.6	35.8	50.6
		18 inches	33.7	32.8	33.7	42.8	55.0	66.8	72.2	70.4	64.9	54.6	43.1	37.6	50.6

EAST LANSING, MICH.—SAND

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(10)	December, 1914, to November, 1915	2 inches	30.6	32.2	34.3	56.2	58.7	70.0	76.2	70.8	68.2	54.1	41.1	30.2	51.9
		4 inches	31.3	32.7	34.5	54.4	58.1	68.6	75.0	70.0	67.4	54.0	41.5	31.8	51.6
(10)	December, 1911, to November, 1915	6 inches	30.5	30.5	33.6	47.7	58.5	69.9	74.5	71.4	65.3	53.0	40.5	33.8	50.8
(10)	December, 1911, to November, 1914	12 inches	32.2	31.4	33.4	42.9	56.3	67.8	72.8	70.7	64.5	53.6	41.9	36.0	50.3
		18 inches	34.3	33.0	33.9	42.5	54.4	65.5	71.1	69.9	64.8	55.0	43.8	38.3	50.5

EAST LANSING, MICH.—CLAY

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(10)	December, 1914, to November, 1915	2 inches	31.9	32.1	33.9	54.4	57.4	67.8	74.4	69.4	66.7	52.9	41.1	32.3	51.2
		4 inches	32.0	32.3	33.7	52.0	55.3	65.5	71.6	68.2	65.5	52.3	41.2	33.0	50.2
(10)	December, 1911, to November, 1915	6 inches	31.3	30.9	33.2	45.7	57.2	68.8	73.8	70.5	64.8	52.8	41.2	34.4	50.4
(10)	December, 1911, to November, 1914	12 inches	32.7	31.7	32.9	42.3	55.5	67.0	72.2	70.2	64.6	53.5	42.2	36.6	50.1
		18 inches	34.2	32.8	33.3	41.5	54.2	65.3	70.9	69.8	64.9	55.1	43.9	38.2	60.3

EAST LANSING, MICH.—PEAT

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(10)	December, 1914, to November, 1915	2 inches	32.0	31.9	31.9	49.9	56.7	67.5	74.2	69.4	66.9	52.9	40.5	33.3	50.6
		4 inches	31.9	31.7	31.6	46.6	55.0	64.6	71.5	67.5	64.7	51.5	40.7	34.0	49.3
(10)	December, 1911, to November, 1915	6 inches	30.8	30.4	31.4	41.1	56.8	68.5	73.9	71.0	65.1	52.9	40.9	34.7	49.8
(10)	December, 1911, to November, 1914	12 inches	32.6	31.6	31.9	38.6	54.7	66.9	72.1	71.3	65.6	54.8	42.8	36.6	50.0
		18 inches	35.2	33.7	33.4	37.8	53.2	64.5	70.8	70.3	65.6	56.4	45.2	39.2	50.4

WOOSTER, OHIO

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(11)	1924 to April, 1925	1 inch	*30.3	32.5	*35.2	*47.3	50.8	62.6	63.0	[18] 62.3	....	50.4	37.4	32.0	....
		6 inches	*35.0	37.2	*41.0	*44.8	51.8	65.3	68.8	[24] 69.6	....	50.6	40.6	34.4	....

COLUMBUS, OHIO

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(11)	1923	1 inch	....	....	....	....	....	....	....	....	....	....	[4] 43.0	43.4	....
		6 inches	....	....	....	....	....	....	....	....	....	....	[4] 48.4	[30] 49.2	....

LEXINGTON, KY.

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(12)	1922–1927	3 inches	*32.7	*35.5	*42.1	*56.0	*62.8	*74.6	*77.1	*76.7	*73.1	*58.3	*45.6	39.2	56.1
(12)	June, 1928 to June, 1929	4 inches	[24] 20.4	17.3	35.4	[29] 49.8	[24] 55.6	*69.4	75.4	[30] 74.6	63.3	55.8	37.6	[30] 24.4	48.2
(12)	1922–1929	18 inches	*36.3	*35.9	*41.5	*52.0	*57.5	*67.8	*70.6	*73.4	*70.2	*59.8	*49.1	41.1	54.6
(12)	1922–1923	36 inches	*41.8	*40.5	*44.0	*50.3	*56.2	*65.8	*70.5	*73.4	*68.8	*62.0	*53.9	47.5	56.2

PURDUE, IND.—CLEAN CULTIVATION WITH WINTER COVER CROP

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(13)	May, 1913, to May, 1915	6 inches	33.3	35.9	36.4	47.8	57.6	68.8	73.5	73.9	66.0	57.4	45.6	40.6	53.0

PURDUE, IND.—STRAW MULCH

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(13)	May, 1913, to May, 1915	6 inches	36.3	36.2	35.4	42.6	52.4	61.6	67.3	68.2	64.1	57.3	48.0	43.3	51.1

TABLE 1.—*Soil temperatures (°F.)*—Continued

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
		PURDUE, IND.—GRASS LAND													
(13)	May, 1913, to May, 1915	6 inches	35.0	35.6	35.1	49.7	55.5	66.0	71.9	70.6	62.7	54.9	45.6	41.4	52.0
		URBANA, ILL.													
(14)	1897-1916*	Air	26.9	25.4	38.3	50.2	62.4	70.6	75.5	73.3	66.1	54.4	40.9	28.6	51.0
		1 inch	29.2	29.5	39.8	51.0	63.0	72.6	78.2	76.2	69.0	55.5	42.2	32.1	53.2
		3 inches	31.0	30.6	39.5	50.6	62.2	72.2	77.8	75.8	69.0	56.8	43.0	33.4	53.5
		6 inches	32.6	31.5	39.3	49.2	60.5	70.5	75.8	74.8	68.8	57.0	44.0	35.0	53.2
		9 inches	33.2	33.0	39.2	48.7	59.8	69.4	74.7	74.0	68.6	57.4	45.2	36.0	53.3
		12 inches	34.0	33.2	38.6	48.4	58.8	68.0	73.8	73.2	68.2	58.0	46.2	37.4	53.2
		24 inches	37.6	37.1	38.6	47.1	55.4	62.6	68.5	69.7	66.7	59.5	50.6	42.7	53.0
		36 inches	41.0	38.8	40.1	46.0	53.6	60.3	66.0	67.8	66.1	60.7	53.0	45.8	53.3
		CHICAGO, ILL.—ST. IGNATIUS' COLLEGE													
(15)	1897-1900	Air	27.7	25.2	36.4	45.8	60.3	62.9	73.6	70.5	65.5	56.7	41.2	29.8	49.7
		4 feet	43.9	41.0	42.2	46.4	53.4	60.8	67.1	68.5	67.4	60.5	55.2	47.0	54.4
		COLUMBIA, MO.													
(16)	1928	Air			[28] 39.3	[29] 44.3	[30] 57.9	62.5	[30] 71.4	[30] 69.6					
		12 inches			[22] 45.0	[27] 49.5	[23] 57.9	[26] 64.0	[26] 71.4	[26] 72.3	[1] Near top of gentle slope.				
		36 inches			44.8	50.5	61.9	66.9	75.7	74.2					
		12 inches			44.2	49.3	57.4	63.7	70.9	71.6	[2] About 200 feet from [1], a seepy spot on slope.				
		36 inches			45.0	50.2	62.1	66.9	75.4	74.8					
		12 inches			44.4	49.5	59.7	65.3	73.4	73.8	[3] About 400 feet from [1], at lower part of slopo.				
		36 inches			45.1	50.7	63.5	68.0	77.2	76.6					
		FAYETTEVILLE, ARK.													
(17)	May, 1928, to May, 1929	Air	35.8	[29] 33.3	50.9	58.3	*64.6	68.7	77.2	[30] 77.9	68.2	64.6	46.9	[30] 40.1	57.2
		5 inches	40.5	[29] 38.3	51.3	60.6	*65.5	70.7	83.3	[30] 84.9	73.9	69.6	[26] 55.9	[30] 43.9	61.5
		FARGO, N. DAK.—SCIENCE GARDEN													
(18)	1922-1925*	1 inch					62.3	69.7	77.0	76.4	61.2	49.8			
		FARGO, N. DAK.													
(19)	1929-30	Air			*42.9	*54.8	64.4	72.6	70.2						
		½ inch			*44.8	*59.8	68.9	73.7	72.2						
		BROOKINGS, S. DAK.													
(20)	1888	Air (maximum)						84.0	78.2						
		2 inches						81.6	76.4						
		12 inches						69.5	69.7						
		LINCOLN, NEBR.—BARE SOIL													
(21)	1900-1904	Air	29.2	25.1	42.8	56.5	67.8	75.6	82.7	79.1	68.4	60.7	42.5	28.8	54.9
		1 inch	30.0	28.2	42.4	58.6	74.5	82.3	90.8	85.6	72 0	60.0	43.5	31.0	58.2
		3 inches	30.0	28.7	41.1	59.3	72.1	81.2	88.6	85.3	72.9	61.4	44.3	31.6	58.0
		6 inches	29.6	28.0	37.9	54.5	68.7	77.5	83.6	82.0	71.0	60.2	44.1	31.9	55.8
		9 inches	30.0	28.4	35.7	50.8	64.4	73.0	79.4	77.9	70.5	59.0	44.3	33.4	53.9
		12 inches	31.4	29.3	35.0	48.2	60.8	69.5	75.8	75.0	66.6	58.4	45.1	34.8	52.5
		24 inches	35.1	32.9	34.7	44.8	56.5	64.2	70.8	71.6	66.9	59.7	49.5	39.5	52.2
		36 inches	38.1	35.3	35.7	43.0	53.2	61.1	67.5	69.4	66.7	60.7	52.1	43.2	52.2
		LINCOLN, NEBR.													
22	1894-1904*	1 inch	28.2	28.0	40.1	58.7	70.9	79.2	86.9	85.1	73.7	58.1	40.6	31.2	56.7
	1894-1904*	3 inches	38.5	27.8	38.8	57.6	69.7	78.1	85.1	84.0	73.5	59.4	42.7	31.4	56.4
	1894-1904*	6 inches	29.0	28.1	37.4	53.6	66.7	76.1	82.1	80.9	72.0	58.3	42.6	31.7	54.9
	1894, 1898-1904*	9 inches	29.8	28.0	36.0	50.8	64.2	73.7	79.7	78.9	71.0	58.5	38.9	28.8	53.2
	1894-1904*	12 inches	30.2	29.9	35.6	49.1	61.2	69.7	75.8	75.6	69.2	57.9	44.5	34.6	52.8
	1894-1904*	24 inches	35.1	33.1	35.3	45.4	56.9	64.6	70.5	72.0	68.2	60.0	49.2	39.5	52.5
	1894-1904*	36 inches	38.1	35.1	36.0	43.6	53.8	61.5	67.7	69.8	67.9	61.3	51.9	43.0	52.5
		MANHATTAN, KANS.—FURROWS													
23	1914-1919	Surface			28.4	Average for 5 winters from December to February or March.									
		2-inch furrow			28.8										
		4-inch furrow			30.0										
		6-inch furrow			30.2										
		TEMPLE, TEX.													
24	1921-1924	Air	51.5	53.2	59.8	68.0	75.6	83.4	87.1	88.6	79.9	68.7	61.0	54.4	69.3
	1918-1924	1 inch	53.1	52.6	59.4	69.1	78.8	88.6	93.7	93.2	83.8	72.6	59.8	52.6	71.4
	1918-1924	3 inches	53.2	52.3	58.6	67.9	78.3	86.5	92.2	93.3	83.9	73.1	60.2	52.8	71.0
	1918-1924	6 inches	53.3	52.7	58.7	67.5	77.3	85.6	91.7	92.3	83.8	73.3	60.9	53.4	70.9
	1918-1924*	12 inches	54.6	53.5	58.1	65.9	74.9	83.4	87.8	88.9	83.8	74.8	62.9	55.4	70.3
	1918-1924	24 inches	56.9	55.2	58.2	64.8	72.1	78.9	84.2	86.9	83.6	76.3	67.0	59.5	70.3
	1918-1924	36 inches	59.6	57.4	59.0	64.2	70.2	76.4	81.7	84.4	83.3	78.7	71.0	62.9	70.7
	1918-1924	48 inches	61.1	58.9	59.0	63.6	68.7	74.0	79.2	82.2	82.1	79.2	73.2	65.0	70.5

TABLE I.—*Soil temperatures (°F.)*—Continued

BOZEMAN, MONT.

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
25	1916–1920	1 foot	29.7	29.1	30.2	35.0	44.2	55.4	64.4	62.9	55.4	44.6	35.4	31.5	43.2
		2 feet	31.8	30.7	31.4	34.8	42.8	52.3	60.0	61.4	56.2	47.0	38.6	34.1	53.4
		3 feet	33.5	32.2	32.0	34.1	40.0	48.7	56.1	58.1	55.1	47.6	39.9	35.6	42.7
		4 feet	36.0	34.4	33.6	34.6	38.8	46.1	53.8	57.3	55.2	49.2	42.8	38.3	43.3
		5 feet	37.7	35.7	34.7	35.3	38.8	44.8	51.0	54.2	53.7	49.8	44.4	40.2	43.4
		7.5 feet	41.2	39.3	37.9	37.4	38.7	42.0	46.6	50.8	51.9	50.0	46.4	43.4	43.8
		10 feet	41.8	39.8	38.5	37.9	38.7	41.7	46.1	50.0	51.4	50.1	46.9	43.9	43.9

MOSCOW, IDAHO

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
26	1898, 1899, and 1901 (1901 only in January, February, March, October, November, and December)	1 inch				40.7	49.4	57.1	63.8	63.4	52.7	47.0	38.2	32.2	
		3 inches	30.8	28.8	34.4	41.2	51.2	58.0	64.1	67.5	54.6	47.8	40.8	33.8	46.1
		6 inches	31.8	30.2	34.6	42.9	48.6	56.0	63.6	65.4	56.8	50.5	41.6	34.6	46.4
		9 inches	32.8	31.0	35.0	45.9	48.9	54.8	62.9	64.9	57.5	51.8	42.8	36.4	47.1
		12 inches	38.2	32.8	35.4	44.7	48.4	54.8	62.2	64.3	58.1	52.2	43.6	37.4	47.7
		24 inches	35.8	34.5	36.2	44.5	47.5	52.9	59.2	62.5	58.2	53.2	45.8	39.2	47.5
		36 inches	37.8	36.2	37.0	40.5	46.2	50.1	55.9	60.0	57.8	53.8	48.0	41.6	47.1
		4 feet	39.8	38.0	38.0	40.5	45.4	48.8	53.7	58.1	57.1	53.8	48.8	43.4	47.1
		5 feet	40.8	39.5	38.8	40.6	44.6	47.5	51.8	56.3	56.5	54.0	49.6	44.6	47.0
		6 feet	42.8	40.8	39.6	41.5	44.6	47.1	50.6	54.7	55.5	54.0	51.6	46.2	47.4

FORT COLLINS, COLO.

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(27)	1889–1927	3 inches	27.7	29.6	36.5	46.6	56.5	66.7	71.4	69.3	61.1	48.3	36.7	29.7	48.3
		6 inches	29.3	30.6	37.1	47.4	56.6	67.0	71.9	70.4	62.8	50.8	39.0	30.2	49.4
		1 foot	32.8	31.1	36.6	45.5	55.8	65.5	70.9	70.1	63.7	52.3	40.7	33.2	49.8
		2 feet	32.9	32.7	36.8	45.3	53.3	62.5	68.5	68.8	64.0	54.4	43.7	36.5	50.0
		3 feet	35.4	32.6	37.1	43.6	51.1	59.1	65.2	66.6	63.4	55.5	46.0	38.9	49.5
		6 feet	42.5	40.5	40.8	44.2	48.8	54.2	59.2	61.8	62.0	58.0	52.1	46.5	50.9

SANTA CATALINA MOUNTAINS, ARIZ.

Reference No.	Year	Depth	Elevation	Slope	Maximum	Minimum	Range	Mean
			Feet					
(28)	Averages of 18 weekly readings of soil temperatures, summer of 1922	3 inches	9,000	North	59.3	53.1	6.2	56.2
			9,000	South	77.7	61.6	16.1	69.6
			8,000	North	62.4	56.5	5.9	59.4
			8,000	South	82.6	60.9	21.7	71.8
			7,000	North	78.9	50.6	28.3	64.7
			7,000	South	91.9	61.3	30.6	76.6

PULLMAN, WASH.—BLUEGRASS SOD

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(29)	April, 1912, to January, 1913	1 inch	31.7			46.5	60.2	62.7	66.0	75.4	60.2	42.0	40.0	33.2	
		2 inches	31.9			45.4	57.8	63.2	65.9	73.2	58.9	42.0	39.9	33.7	
		6 inches	32.3			44.7	54.9	62.3	64.8	70.2	57.2	42.4	40.4	34.5	
		1 foot	32.7			44.8	52.8	62.2	64.9	67.7	56.7	45.0	42.2	36.0	
		2 feet	35.6			44.3	50.6	59.0	62.8	66.5	58.5	48.5	45.0	39.2	
		3 feet	37.5			44.1	48.9	56.3	60.9	64.8	58.9	50.9	47.4	41.9	

PENDLETON, OREG.—DRY, LIGHT SOIL, THIN GRASS

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(30)	1890	Air	21.0	30.1	42.0	52.2	60.1	63.0	68.8	68.8	60.0	49.6	40.4		
		4 inches	26.7	37.3	44.9	62.2	72.3	74.2	84.6	83.3	73.2	57.4	45.8		
		8 inches	27.8	36.6	40.9	55.3	66.3	68.4	77.6	75.8	66.5	53.7	43.2		
		12 inches	30.4	37.1	39.8	52.2	63.1	65.8	73.7	73.3	65.7	54.7	45.2		
		24 inches	34.6	38.1	40.1	50.1	60.9	63.7	71.0	71.7	66.7	57.3	48.5		

CORVALLIS, OREG.—WET AND DRY SOILS UNDER ALFALFA AND CLOVER COVERS

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(31)	1910	Air							[3] 81.8	[4] 71.9	[3] 71.8				
		3 inches, dry							[3] 80.7	[4] 77.8	[3] 70.5	Average, under alfalfa and clover.			
		3 inches, wet							[3] 76.2	[4] 71.6	[3] 64.5				
		3 inches, dry							[3] 82.0	[4] 77.5	[3] 71.0	Under alfalfa.			
		3 inches, wet							[3] 77.0	[4] 71.8	[3] 64.0				
		3 inches, dry							[3] 79.3	[4] 78.0	[3] 70.0	Under clover.			
		3 inches, wet							[3] 75.5	[4] 71.5	[2] 65.0				

DAVIS, CALIF.—DEEP, RECENT ALLUVIAL SOIL, UNCROPPED

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(32)	February to September, 1925, and January to June, 1927.	Air	44.8	49.9	51.6	54.2	60.3	69.1	75.6	70.8	63.6				
		½ inch	48.0	51.1	58.4	63.2	74.8	82.0	90.6	86.0	77.4				
		3 inches	48.2	49.9	55.2	61.9	72.9	78.9	86.6	83.2	76.4				
		6 inches	48.8	50.2	54.5	60.9	72.0	78.0	87.2	84.5	79.4				
		12 inches	48.5	50.2	53.7	60.2	70.8	76.4	84.4	83.0	77.2				
		24 inches	53.2	51.9	54.6	59.7	68.4	72.9	82.8	82.8	78.2				
		36 inches	51.2	51.4	54.3	60.1	68.8	72.9	80.8	82.5	78.6				

TABLE 2.—*Mean daily ranges—Soil and air temperatures (° F.)*

[Superior figures in figure columns are additional references under "Literature Cited" at end of article]

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
NEW HAVEN, CONN.—SANDY LOAM, LEVEL, EXPOSED TO SUN															
(4)	1926	Air					[31] 14.2	11.1	11.2	10.6	10.7	8.3	[24] 9.6		
		3 inches					[8] 11.6	[29] 13.1	6.4	[30] 11.0	[28] 10.9	6.1	[18] 5.6		
		6 inches					[8] 6.2	[29] 7.4	8.7	[30] 5.8	[27] 6.6	4.4	[17] 3.0		
		9 inches					[9] 3.5	3.5	2.5	[30] 1.9	[28] 2.6	1.4	[19] 1.6		
		12 inches					[8] 1.6	[29] 1.7	1.2	[30] 1.0	[28] 1.3	[30] 1.1	[18] 0.9		
NEW HAVEN (YALE UNIVERSITY)—TEMPERATURES TAKEN IN BORINGS IN THE SOIL															
(5)	1924	Air				20.1	17.5								
		6 inches				6.3	6.8								
		12 inches				5.7	6.6								
		18 inches				3.3	2.9								
NEW YORK BOTANICAL GARDENS—CLAY SOIL MIXED WITH LOAM															
(6)	1902	Air						[22] 18.9	17.7	20.0	16.9	[28] 16.9	[22] 15.8	[14] 11.2	
		12 inches						[21] 2.6	2.5	[29] 1.4	1.4	1.2	0.9	[21] 1.1	
ATHENS, GA.—LAND BEDDED UP FOR COTTON															
(8)	1926	Air			26.7	Average from Apr. 22. to May 20.									
		1.5 inches			18.9										
WOOSTER, OHIO															
(11)	1924 to April, 1925	1 inch	*3.6	5.3	*11.6	*21.8	22.2	23.2	22.9	[15] 17.0		16.9	8.5	4.9	
		6 inches	*1.0	1.2	*3.3	*7.3	7.8	9.0	8.3	[24] 8.4		3.3	2.7	1.5	
COLUMBUS, OHIO															
(11)	1923	1 inch											[4] 6.9	9.8	
		6 inches											[4] 1.1	[30] 2.5	
LEXINGTON, KY.															
(12)	1924–1927*	3 inches	1.2	3.2	5.8	7.5	6.2	7.7	8.7	7.1	8.4	6.9	5.1	4.3	6.0
	June, 1928, to June, 1929	4 inches	[24] 2.9	1.0	8.1	[30] 7.6	[24] 6.5	5.7	10.2	[30] 8.2	7.4	6.5	5.5	[30] 3.7	6.1
	1924–1927*	18 inches	0.8	1.6	0.9	1.0	1.0	0.8	0.9	0.8	0.8	1.1	1.0	1.4	1.0
PURDUE, IND.—CLEAN CULTIVATION WITH WINTER-COVER CROP															
(13)	May, 1913 to May, 1915	6 inches	1.4	5.4	6.7	11.9	10.8	9.2	9.4	8.2	11.7	7.6	10.3	5.2	8.2
PURDUE, IND.—STRAW MULCH															
(13)	May, 1913, to May, 1915	6 inches	1.8	2.7	1.6	5.3	3.5	3.7	2.6	3.2	4.2	3.8	4.4	3.5	3.4
PURDUE, IND.—GRASS LAND															
(13)	May, 1913, to May, 1915	6 inches	2.1	4.1	3.8	9.0	9.8	8.7	8.4	6.8	7.4	5.0	7.7	4.7	6.5
FARGO, N. DAK.—SCIENCE GARDEN															
(18)	1922–1925*	1 inch					27.9	30.2	36.3	43.8	32.9	22.3			
FARGO, N. DAK.															
(19)	1929–30	Air				*21.8	*24.9	26.6	28.5	25.4					
		½ inch				*8.0	*7.0	9.0	15.9	13.6					

TABLE 3.—*Mean monthly ranges—Soil and air temperatures (° F.)*

[Superior figures in figure columns are additional references under "Literature cited" at end of article]

Reference No.	Years	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Mean annual monthly range
NEW HAVEN, CONN.—SANDY LAOM, LEVEL, EXPOSED TO SUN															
(4)	1926	Air					[8] 33.0	37.0	41.0	39.0	35.0	34.0	[14] 37.0		
		3 inches					[8] 27.0	[29] 38.0	38.0	[30] 33.0	[28] 26.0	34.0	[18] 27.0		
		6 inches					[8] 18.0	[29] 26.0	26.0	[30] 21.0	[27] 21.0	27.0	[17] 19.0		
		9 inches					[9] 14.0	16.0	14.0	[30] 15.0	[28] 14.0	15.0	[19] 16.0		
		12 inches					[9] 10.0	[29] 11.0	11.0	[30] 12.0	[28] 12.0	[30] 18.0	[18] 14.0		
NEW YORK BOTANICAL GARDENS—CLAY SOIL MIXED WITH LOAM															
(6)	1902	Air						[22] 40.5	37.4	37.4	44.8	[28] 43.6	[23] 40.5	[14] 36.9	
		12 inches						[21] 7.2	10.8	[29] 9.0	11.7	13.3	0.9	[21] 2.2	
WOOSTER. OHIO															
(11)	1924 to April, 1925	1 inch	* 17.4	26.7	* 23.2	* 44.4	42.5	42.0	34.5	[15] 30.5	34.5		30.0	28.0	
		6 inches	* 6.8	11.6	* 13.3	* 27.5	23.0	27.5	18.5	[24] 19.0	18.5		19.5	12.5	
COLUMBUS, OHIO															
(11)	1923	1 inch											[4] 10.0	20.0	
		6 inches											[4] 3.5	[30] 1.0	
LEXINGTON, KY.															
(12)	1924–1928*	3 inches	14.5	13.0	26.3	31.7	19.3	18.3	17.2	17.8	16.2	25.5	[27] 28.0	28.5	21.4
	July, 1928, to June 1929	4 inches	[24] 20.5	13.5	37.5	21.0	[24] 16.5	[6] 5.5	[9] 7.0	[30] 20.0	25.5	29.0	29.5	18.5	20.3
	June, 1928 to May, 1929	8 inches	[24] 12.5	8.5	23.0	10.0	[24] 14.0	[19] 9.5	[9] 8.0	[30] 10.5	[20] 16.0	17.0	16.5	13.0	13.2
	1924*–1927*	18 inches	8.3	16.3	11.2	12.3	7.2	9.5	10.2	5.0	10.5	9.5	16.0	12.0	10.7
FARGO, N. DAK.—SCIENCE GARDEN															
(18)	1922–1925*	1 inch					58.9	56.7	60.8	67.0	[8] 38.3	[17] 48.1			
FARGO, N. DAK.															
(19)	1929–30	Air				* 47.0	* 66.2	60.2	62.0	59.0					
		½ inch				* 27.0	* 38.5	30.5	42.5	38.5					
TEMPLE, TEX.															
(24)	1921–1924	Air	59.2	53.8	51.2	45.2	38.5	31.5	31.8	36.0	42.5	54.2	55.0	41.5	45.0
	1918–1924	1 inch	41.4	37.2	39.7	39.6	35.4	37.4	39.3	37.7	42.1	42.5	41.8	41.8	39.7
	1918–1924	3 inches	32.9	30.9	33.9	32.6	30.4	30.8	30.6	29.3	33.3	35.9	35.0	35.1	32.6
	1918–1924	6 inches	28.2	23.5	26.1	25.3	25.3	24.1	23.3	21.7	25.6	29.7	27.1	26.7	25.6
	1918–1924*	12 inches	19.0	16.8	13.8	14.0	15.8	8.9	10.5	7.7	12.6	17.8	15.8	20.7	14.4
	1918–1924	24 inches	11.9	10.5	9.7	8.1	11.5	8.4	5.4	5.5	6.6	10.0	10.5	12.3	9.2
	1918–1924	36 inches	10.1	6.6	4.9	5.8	7.9	6.1	4.1	4.4	4.4	6.6	9.4	10.1	6.7
	1918–1924	48 inches	7.1	6.5	2.8	4.7	6.2	7.0	3.8	3.2	2.6	5.3	7.0	10.8	5.6

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RESOLUTIONS PASSED BY THE POLAR YEAR COMMISSION OF THE INTERNATIONAL METEOROLOGICAL COMMITTEE AT LENINGRAD, AUGUST, 1930 [1]

Upon the invitation of the Academy of Sciences and of the hydrometeorological committee of the Union of Socialist Soviet Republics received through Prof. A. P. Karpinsky, president of the Academy of Sciences, a conference of the International Commission for the Polar Year of 1932–33 was held in Leningrad, August, 26–30, 1930, under the presidency of Dr. D. la Cour. The international commission was represented at this conference by Messrs. D. la Cour (Denmark), H. Dominik (Germany), J. A. Fleming (United States), H. Hergesell (Germany), W. E. W. Jackson (Canada), A. P. Karpinsky (Union of Socialist Soviet Republics), J. Keränen (Finland), Ch. Maurain (France), G. C. Simpson (Great Britain), H. U. Sverdrup (Norway), and A. Wangenheim (Union of Socialist Soviet Republics). There were also present, as the guests of the international commission, Messrs. H. D. Harradon (United States) and V. Laursen (Denmark), and Miss Bruun de Neergaard (Denmark).

The following scientists of the Union of Socialist Republics participated in the sessions of the conference: A. P. Karpinsky, president of the Academy of Sciences and of the Polar Commission of the Union of Socialist Soviet Republics, member of the International Commission for the Polar Year of 1932–33; A. Wangenheim, president of the hydrometeorological committee of the Union of Socialist Soviet Republics, member of the International Commission for the Polar Year of 1932–33; J. Schokalsky, president of the Geographical Society of Russia, corresponding member of the Academy of Sciences, and member of the Polar Commission of the Union of Socialist Republics; L. Rudowitz, chief of the hydrometeorological department of the Hydrographic Office; A. M. Lawrow, member of the Polar Commission of the Union of Socialist Soviet Republics, collaborator of the Hydrographic Office; N. Rose, collaborator of the Central Geophysical Observatory and member of the Polar Commission of the Union of Socialist Soviet Republics; W. N. Obloensky, V. Schuleikin, B. Weinberg, A. Kaminsky, A. Schönrock, W. Arnold-Alabjew, and M. Kartzeff, collaborators of the Central Geophysical Observatory; W. Schostakowitsch, collaborator of the Central Geophysical Observatory, former director of the Geophysical Observatory at Irkutsk; A. Tolmatchew, secretary of the Polar Commission and of the local committee on the Polar Year of the Union of Socialist Soviet Republics, chief of the expedition of the Academy of Sciences of the Union of Socialist Soviet Republics to the region of Petchora; D. Rudnew, member of the Polar Commission of the Union of Socialist Soviet Republics; P. Moltschanow, director of the Aerological Observatory at Sloutzk; Trutnew, director of the Geophysical Observatory at Irkutsk; A. W. Sokolow, collaborator of the hydrometeorological committee of the Union of Socialist Soviet Republics; W. Timonoff, collaborator of the National Hydrological Institute; N. N. Kalitin, director of the Actinometric Institute at Sloutzk; R. Khuzechwili, director of the Magnetic Observatory at Sloutzk; V. Akhmatow, vice director of the Hydrographic Office.

The principal objects of the conference were to receive reports on the actual state of preparation in the various countries for the work of the polar year, the actions taken by the international organizations to support the project, and to consider in more detail the research program which may be accomplished. It appeared from the proceedings and discussions of the conference that unusual interest is being evidenced everywhere in the successful outcome of the plans for the polar year of 1932–33.

As the result of this conference and following discussion of the reports submitted, some 22 resolutions were adopted which are briefly summarized below.

1. The polar year of 1932–33 is designated to begin August 1, 1932, and to continue for 13 months through August 31, 1933, that is, the actual period of recorded observations is not to be less than 13 months.
2. It is desirable that all stations taking part in the program for the polar year zonal time should be used, that is, Greenwich mean time $\pm$ n hours, where n is a whole number.
3. The desirable network of magnetic stations north of 55° latitude recommended is as follows: Lerwick, Shetland Islands; Eskdalemuir, Scotland; Jan Mayen Island; station on east coast and station on west coast of Iceland; Mygbugten, Scoresby Sound, Angmagssalik, Ivigtut, Godthaab, Godhavn, and Thule (Cape York), Greenland; Lady Franklin Bay (Fort Conger), Ellesmere Island; Kingua Fiord, Baffin Island; Chesterfield, Fort Rae, and Meanook, Canada; Sitka and Fairbanks, Alaska; Yellen (East Cape), Nijni Kolymsk, Yakutsk, Bulun, Dickson, and Sverdlovsk, Siberia; Matochin Shar, Novaya Zemlya Island; Hooker Island, Franz Josef Land; Kazan, Kouchino, Kandalaksha, and Sloutzk (Pavlovsk), Union of Socialist Soviet Republic; Petsamo and Sodankylä, Finland; Hammerfest or Bossekop, Kautokeino, Abisko, and Tromsö, Norway; Bear Island; Spitzbergen; Stockholm (Lovö), Sweden; and Copenhagen (Rude Skov), Denmark. (For 21 of these stations definite provision is already made.)
4. The establishment of the magnetic stations proposed by the national committees of various countries but not yet assured, is considered of very great importance for the work of the polar year, and the commission recommends very strongly their establishment.
5. Since a station in Lady Franklin Bay would be located near the station Thule (Cape York, Greenland) but on the opposite side of the magnetic axis of the earth (and between it and the north geographic pole), it is of urgent importance that a magnetic station be established in the vicinity of Lady Franklin Bay.
6. In view of the location of Iceland near the zone of maximum frequency of the aurora, the commission recommends establishing two magnetic stations in Iceland, one toward the west and the other toward the east.
7. It is important that there be a network of magnetic stations also in the Antarctic, which may be furthered through the help of whalers stationed in the Antarctic; there should be especially a station as close as possible to the south magnetic pole.
8. The commission is pleased to note that the Republic of Argentina will collaborate in the polar year at the station in the South Orkneys, and hopes that that Government will renew the old station on New Year's Island.
9. In view of the importance of a knowledge of the magnetic field and of its variation in the vast extent of the oceans, the establishment of magnetic stations on Easter Island, on the island of Tristan da Cunha in the southern Atlantic, and on the Kerguelen Islands in the Indian Ocean is strongly recommended.
10. It is desirable that the special polar year program of magnetic observations be continued as long as possible over the whole world. In the Antarctic the observations should begin if possible half a year before and continue half a year after the polar year as above defined.
11. The commission recommends making magnetic observations with registering apparatus of great speed, according to proposals which will be communicated later.
12. All types of instruments that have not already been used in the polar regions, but which will be used during the polar year, should be tested as soon as possible by actual use at an Arctic station. (The Finnish Government has offered the use of its station and facilities at Sodankylä for this purpose and for the instruction of observers.)
13. It is desirable that the magnetic program of the commission be sent to all the observatories of the world, with the request that each cooperate in following that program; this is especially the case for those observatories situated in regions where there are few observatories.
14. In view of the importance of the researches considered by the commission of all magnetic data relating to the polar regions, catalogues of magnetic determinations in the polar regions pre-

[1] Abstracted by J. A. Fleming and W. J. Peters from the minutes of the meeting supplied by the chairman, D. la Cour. For the resolutions passed at the Copenhagen meeting in September, 1929, at which provision for the Polar Year Commission, 1932–33 was made, see Terr. Mag., 34, 1929 (317–318).

pared by W. J. Peters of the Carnegie Institution of Washington and B. Weinberg of the Central Geophysical Observatory of Leningrad should be published by the Union of Socialist Soviet Republics, if possible, before the polar year.

15. The commission regards the following mountain stations desirable for the execution of the meteorological program: 2 on the west coast, 1 near the southern coast, 2 on the east coast, and 1 on the northeastern coast of Greenland; 2 on Iceland; 1 on Jan Mayen Island; 1 on the Faroe Islands; 2 in Norway; 1 in Spitzbergen; 1 on the Kola Peninsula at Chibiny; 1 at Matochin Shar; 1 in Franz Josef Land; 1 at Boulbouh (Verkhoyansk Mountains); and 1 near Bering Strait.

16. For the execution of the aerological program, five stations around the Arctic are desired and it is recommended that one each be established in Alaska, in Canada, in Greenland, in Spitzbergen, and in the Union of Socialist Soviet Republic.

17. The countries interested in the polar year are requested to arrange for pilot-balloon stations on board as well as for the careful training of the personnel of "selected ships" for aerological and meteorological investigations at sea.

18. It is recommended that the program of investigation of the upper layers of the atmosphere submitted by Professor Moltschanow for the study of the temperature-gradient should be supported by the Union of Socialist Soviet Republics, if in any way possible, with the necessary means.

19. The publication in the protocol of the conference was authorized of Prof. A. Kaminsky's communication on investigation of climate in polar regions with recommendation that his proposition be considered especially in regard to establishing observing stations.

20. Having received the report Hydrological investigations in the period of the International Polar Year and the detailed program in hydrology proposed by the institutions of the Union of Socialist Soviet Republics, the commission considers that program important both from the economic viewpoint and the viewpoint of geophysical science, and directs that these documents be submitted to the subcommittee created to consider the questions of exploring the sea during the polar year.

21. The report from the permanent actinometric commission of the hydrometeorological committee of the Union of Socialist Soviet Republics submitted by Prof. M. N. Kalitin on the organization of the actinometric work during the polar year was accepted with thanks and authority given to publish it in the protocol of the conference.

22. The commission on the higher atmosphere, the commission on clouds, and other international commissions are asked to decide upon and to communicate one year before the beginning of the polar year those dates selected for particular programs of observation, in order that they may be included appropriately in the program of the polar year.

Special committees, which were requested to make their reports by the end of 1930, were appointed to consider and prepare reports upon questions relative to standard equipment, to methods of observing and recording, and to publication. The members of the committees are: Publication, Messrs. Simpson, Sverdrup, and Maurain; magnetic instruments, Messrs. Fleming, la Cour, and Keränen; meterological instruments, Messrs, Simpson and Sverdrup; aerological instruments, Messrs. Hergesell and Wangenheim; actinometric instruments, Messrs. Wangenheim and Dominik; atmospheric-electric instruments, Messrs, Maurain, Hergesell, and la Cour; earth-current instruments, Mr. Fleming; instruments for auroral observation, Messrs. Maurain, la Cour, and Keränen.

DEPARTMENT OF TERRESTRIAL MAGNETISM,
CARNEGIE INSTITUTION OF WASHINGTON,
Washington, D. C.

CLIMATOLOGICAL CHARTS FOR THE ALLEGHENY FOREST REGION

By H. F. MOREY

[Allegheny Forest Experiment Station,[1] U. S. Forest Service]

There is a great use for climatological charts in forest research. One of the most frequent uses of such charts is in the study of distribution of forest types and individual tree species. The foundation for the study of the influence of climate on vegetation has been laid by Merriam, Abbe, Livingston, Shreve, among others, and serves as an excellent basis for a more elaborate investigation of any particular region. Bates, at the Lake States Forest Experiment Station, has found that Norway pine in the Lake States, whence comes the bulk of the seed used for artificial reforestation with this species, grows under mean summer temperatures varying only from 56° to 66° F. This is very important from the silvicultural point of view because it has been learned in Sweden that if the variation of the mean summer temperature of a planting site differs by so much as 1° C. (1.8° F.) from that of the seed source, results may be only 65 per cent as good as if home-grown seed had been used. According to Bates, traffic lanes for seed will ultimately be laid along isothermal lines.

Climatological charts of a scale large enough to be useful in regional or local studies are generally available only for the several States. But vegetation recognizes few political boundaries and the Federal forest experiment stations are organized so far as possible on a regional basis. When, therefore, the Allegheny Forest Experiment Station recently undertook to compile charts of precipitation, temperature, and other climatic factors, it was confronted with the task of placing on a single map data from four different States—Delaware, Maryland, New Jersey, and Pennsylvania.

As a result of an inquiry sent to the Weather Bureau section directors of the States concerned and the adjoining States, it was learned that but few charts were available. Virginia and West Virginia had none. The charts procured are listed in Table 1. Summaries "of the climatological data for the United States" were received for all the States.

[1] Acknowledgment: Mr. George S. Bliss, section director, U. S. Weather Bureau, Philadelphia, Pa., gave many helpful suggestions which were followed in the preparation and revision of the charts.

TABLE 1

State	Temperature isotherm interval	Precipitation isohyetal line interval	Growing season days	Frost dates [1]
Delaware	Average annual 1°	Average annual, 2 and 4 inches	Exact average for counties	Exact average for counties.
Maryland	do	do	do	Do.
New Jersey [2]	Mean annual, 1° Mean summer, 1° Mean winter, 1°	Mean annual, 2 inches Mean summer, 2 inches Mean winter, 2 inches	None	None.
New York	Mean annual, 2°	Normal annual, 5 inches	do	Do.
Ohio [3]	Normal annual, 1° Normal monthly, 1°	Normal annual, 3 inches	15-day intervals	5-day intervals.
Pennsylvania [4]	Normal annual, 2° Normal monthly, 2°	Normal annual, 5 inches	do	15-day intervals.

[1] Average date of first killing frost in the spring and average date of last killing frost in the fall.
[2] From the Annual Report of the State Geologist, New Jersey, 1899.
[3] From Alexander, W. H., 1923. A Climatological History of Ohio, Ohio State University. This also included charts for normal monthly distribution of precipitation, and annual snowfall.
[4] From charts furnished by George S. Bliss, section director, at Philadelphia. Charts of normal annual snowfall and normal monthly snowfall were also procured for Pennsylvania.

TABLE 2

Climatic factor	Beech-Birch-Maple [1]	Entire region
Average annual temperature	44° to 49° F	44° to 57° F.
Average dates of last killing frost in spring	4-20 to 6-10 [1]	4-10 to 6-10.
Average dates of first killing frost in fall	9-10 to 10-30 [1]	9-10 to 11-10.
Average length of growing season, days	120 to 165 days	120 to 224 days.
Average summer temperature (June to September, inclusive).	63° to 68° F	65° to 75° F.
Mean minimum summer temperature (June to September, inclusive).	53° to 55° F. [2]	53° to 67° F.
Mean maximum summer temperature (June to September, inclusive).	74° to 79° F. [3]	74° to 85° F.
Average annual precipitation	38 to 50 inches	34 to 50 inches.
Mean summer precipitation (June to September, inclusive).	14 to 19 inches	14 to 20 inches.

[1] General. Few exceptions as noted under factor under consideration. Cities such as Erie and Scranton may have some effect.
[2] Except Scranton (57°) and Erie (60°).
[3] Local variations in Alleghenies to 82°, local climate may vary from that shown on our small scale chart.

Several difficulties arose when an attempt was made to combine the State charts into a regional one. The isotherms and isohyetal lines for one State often failed to connect with the corresponding climatic line in the adjoining State. The base maps of the States were on different scales, and the intervals between the various climatic lines differed. The New Jersey charts were old and did not correspond with the averages of 1920. These differences made it necessary to compile our own regional charts from the data available.

Averages obtained from the summaries "of the climatological data for the United States" were plotted on a large scale map of the region. Average rather than normal values are charted. The distinction between "average" and "normal" is, according to Milham, that average is the "sum of a number of observation divided by the number of observations. If the observations have been extended over a sufficient length of time so that accidental irregularities have been eliminated by taking the average, then the average value may be spoken of as a normal." Where great irregularities were observed, as in some of the shorter records, the data were compared and weighed with data from nearby stations having longer records, according to the method of Reed and Kincer.[1] Topography was used as a guide to the charting of the climatic lines in the mountainous regions. No contour map on a suitable scale was available for the region.

Temperature, precipitation, growing season, and frost charts have been prepared to date, and are presented herewith. The dearth of available drought, humidity, and evaporation data has made it impossible to make charts for these factors.

Several interesting correlations between climate and vegetation have been made with the charts so far prepared. Through the courtesy of the Pennsylvania Department of Forests and Waters [2] a large scale map of the "Beech-birch-maple" type in Pennsylvania was obtained, and the climate of the type as worked out from our charts is given in Table 2.

From the rather sketchy species distribution maps of the Forest Service it has been observed that the southern limit of chestnut oak in Maryland and Delaware practically coincides with the northern limit of loblolly pine. The dividing line roughly follows the 72° average summer isotherm, the 62° mean minimum summer isotherm, and the 82° mean maximum summer isotherm. The average summer precipitation is from 16 to 17 inches. There seems to be no relationship between this dividing line and average annual temperature, average annual precipitation, frost, or growing season, although all of these factors, either singly or collectively, may affect the distribution. Evaporation, humidity, drought, and winter temperature probably play an important part in limiting the northward occurrence of the pine and the southern occurrence of the oak. Loblolly pine has been reported as occurring naturally in Cape May County, but nowhere else in New Jersey. The State forest service, however, has had success in planting loblolly pine in southern New Jersey. That soil is not the chief limiting factor in the distribution of the loblolly pine in New Jersey, is apparent from a study of the soil bulletin for Maryland and New Jersey. Soil types which in New Jersey contain no loblolly pine, have a luxuriant growth of this species in southern Maryland. Unless undetermined chemical or biological differences within the same soil type, in the two States, limit distribution, climate must be the chief limiting factor.

A real knowledge of the climatic conditions of a region, conveniently recorded in the form of charts, is valuable in many less obvious connections. Thus, the fact that cities have an effect upon average temperature, has been revealed in the Allegheny region by our temperature, frost, and growing season charts, and raises a question as to the wisdom of making phenological observations in city parks, a practice at one time considered by the experiment station.

[1] Reed, W. G., and Kincer, J. B., 1917. The Preparation of Precipitation Charts. Mo. Weather Rev. Vol. 45, pp. 233-235.

[2] Illick, Joseph S., and Frontz, Leroy, 1928. The Beech-Birch-Maple Type. Pennsylvania Department of Forests and Waters. Bull. 46.

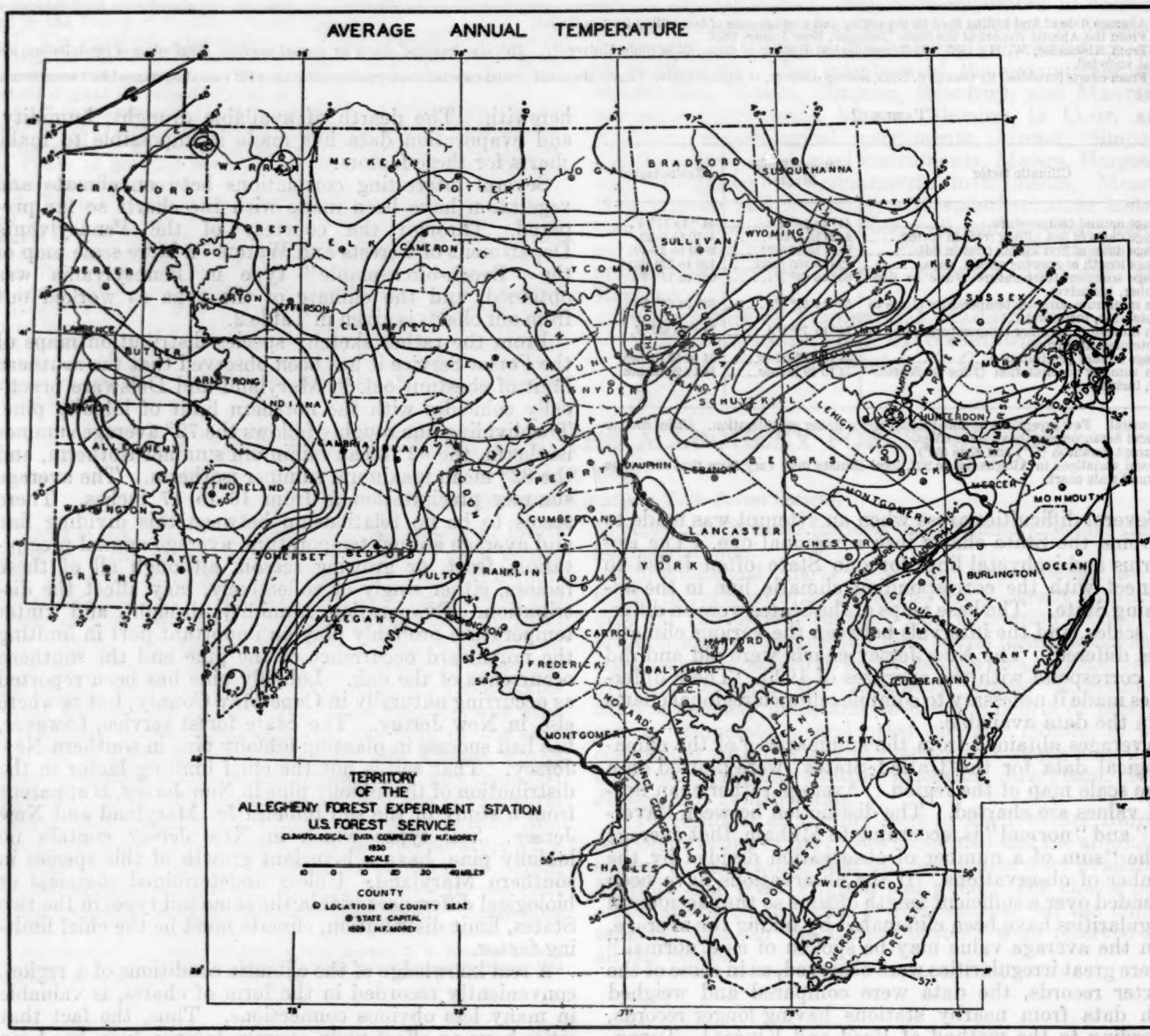

FIGURE 1.—Average annual temperature

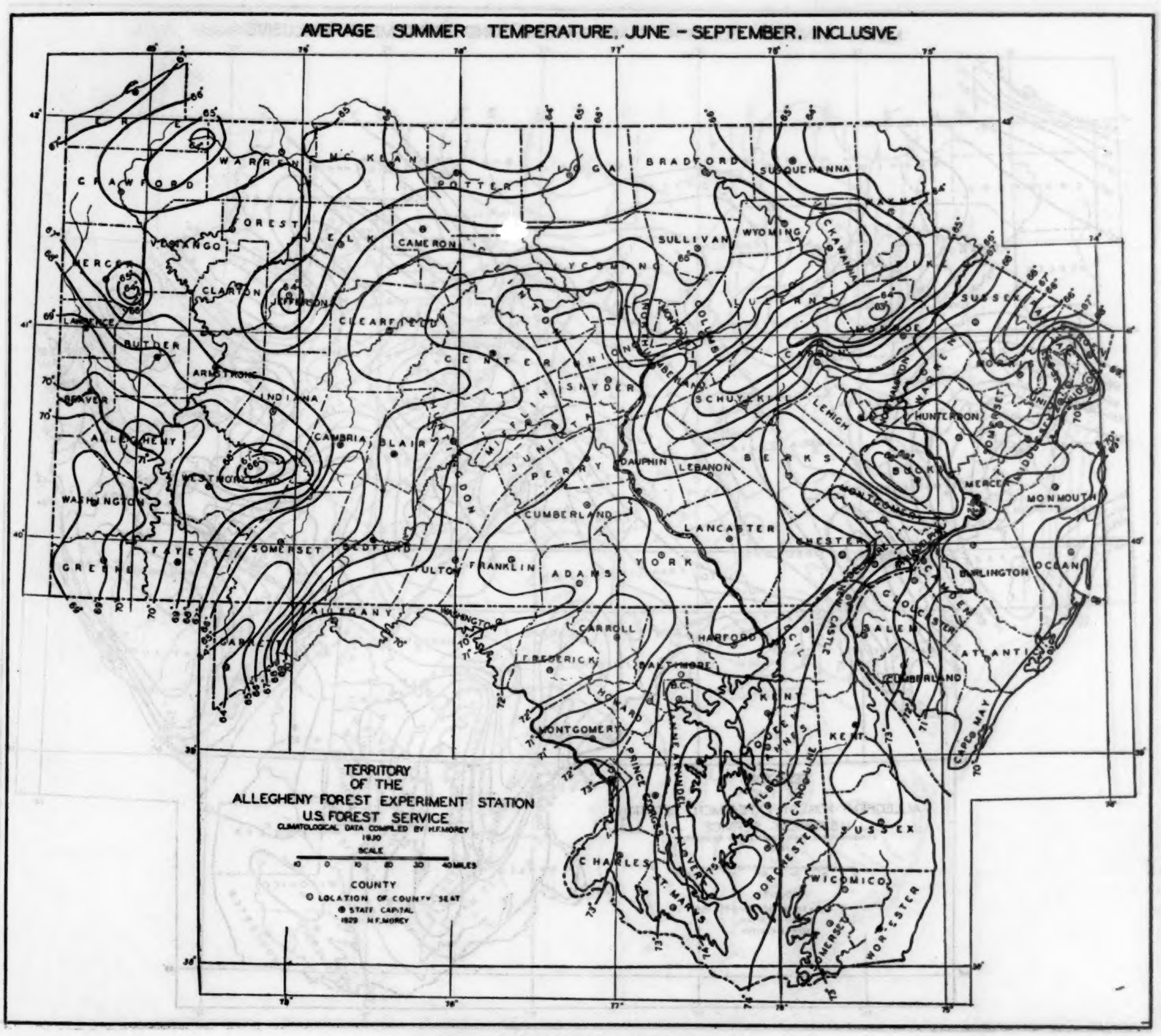

FIGURE 2.—Average summer temperature

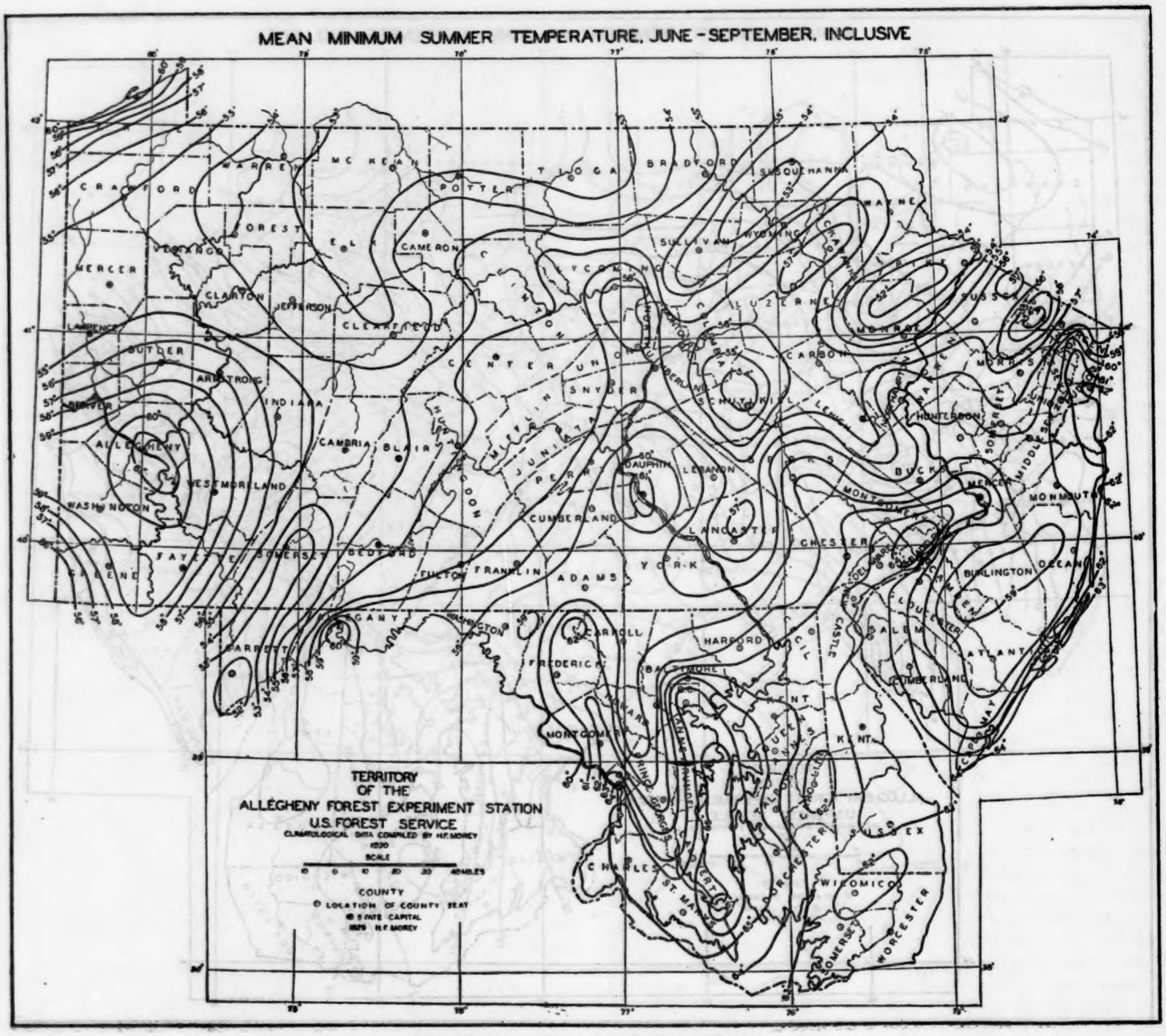

FIGURE 3.—Average summer minimum temperature

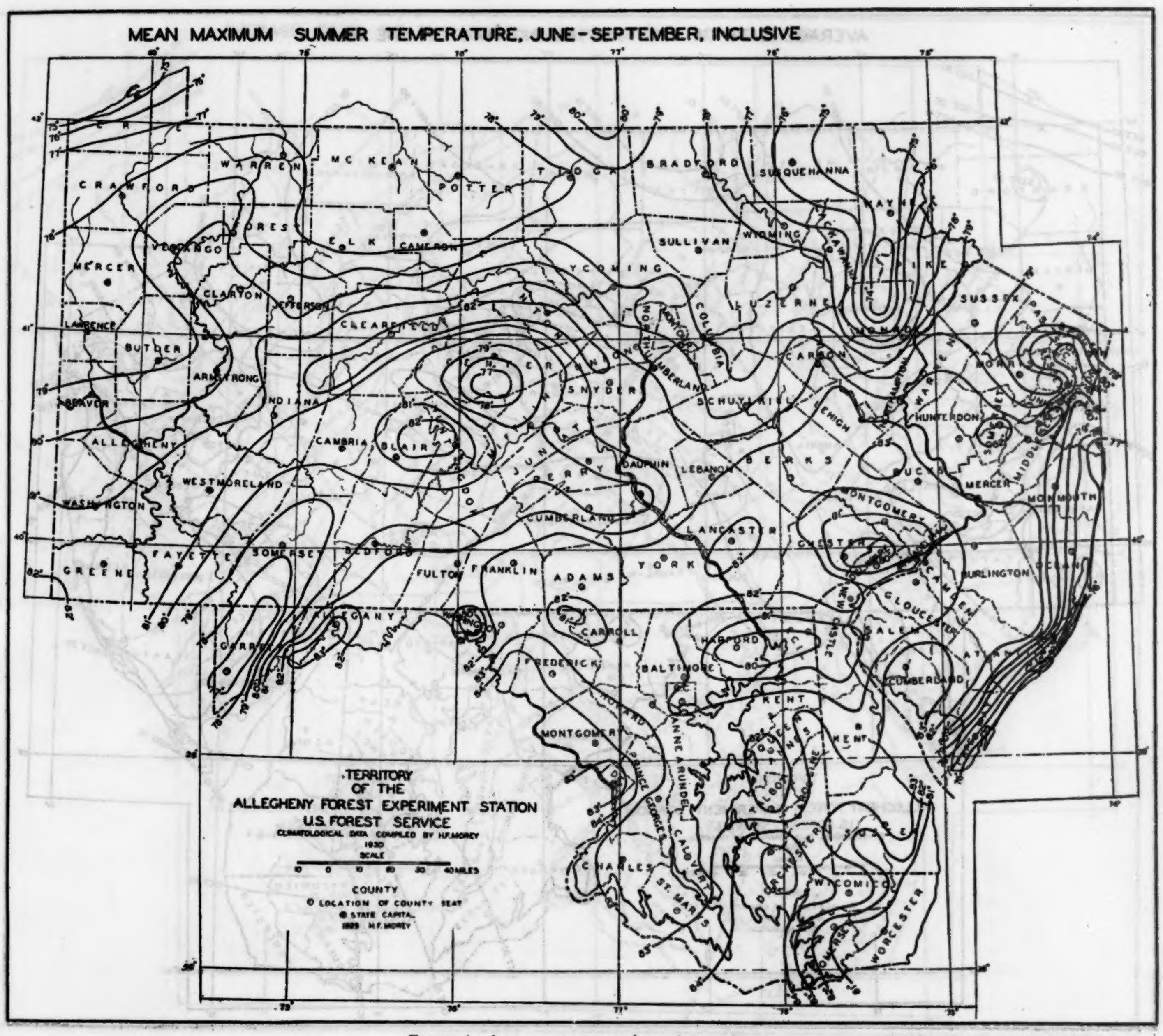

FIGURE 4.—Average summer maximum temperature

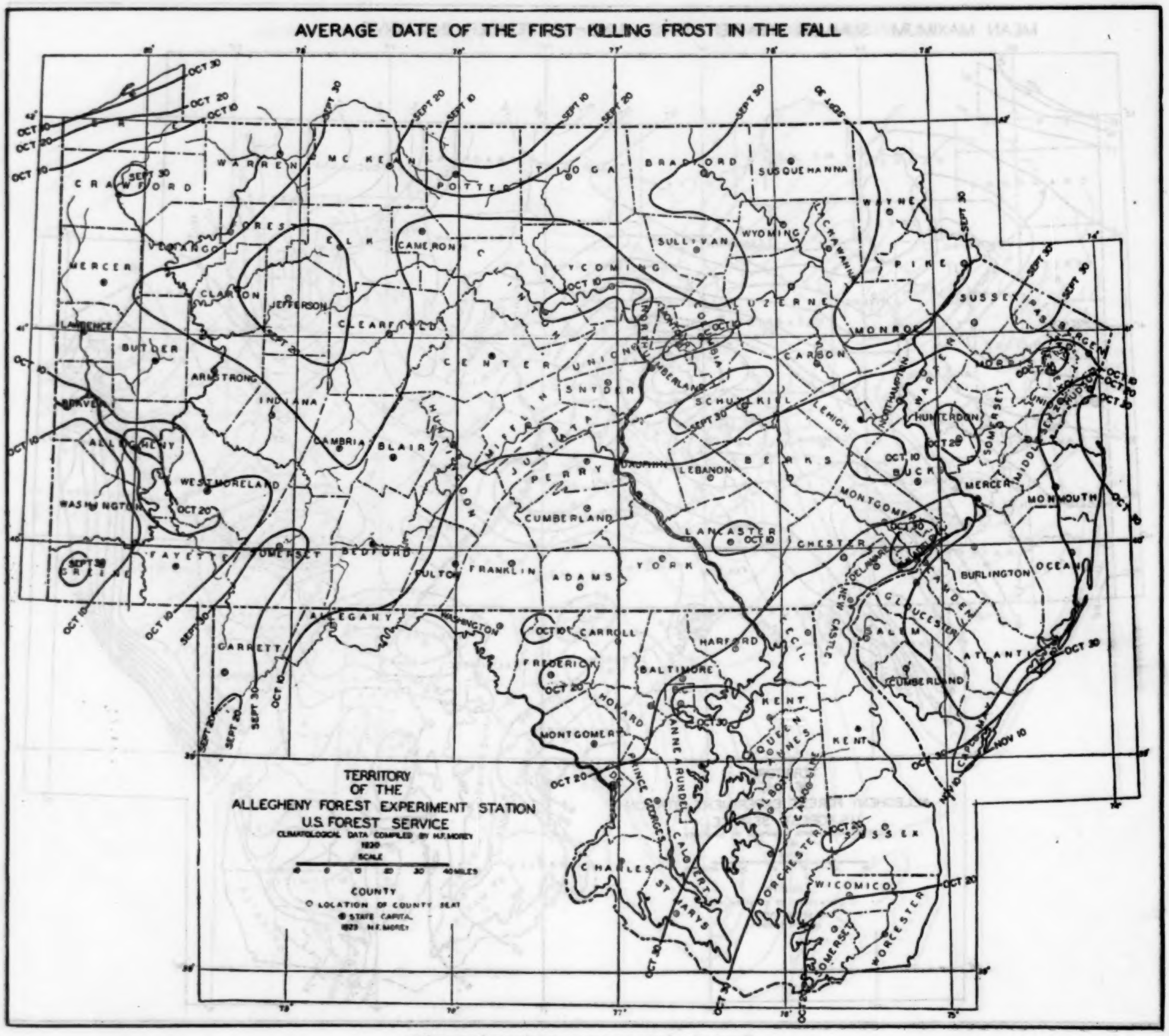

FIGURE 5.—Average date of first killing frost in fall

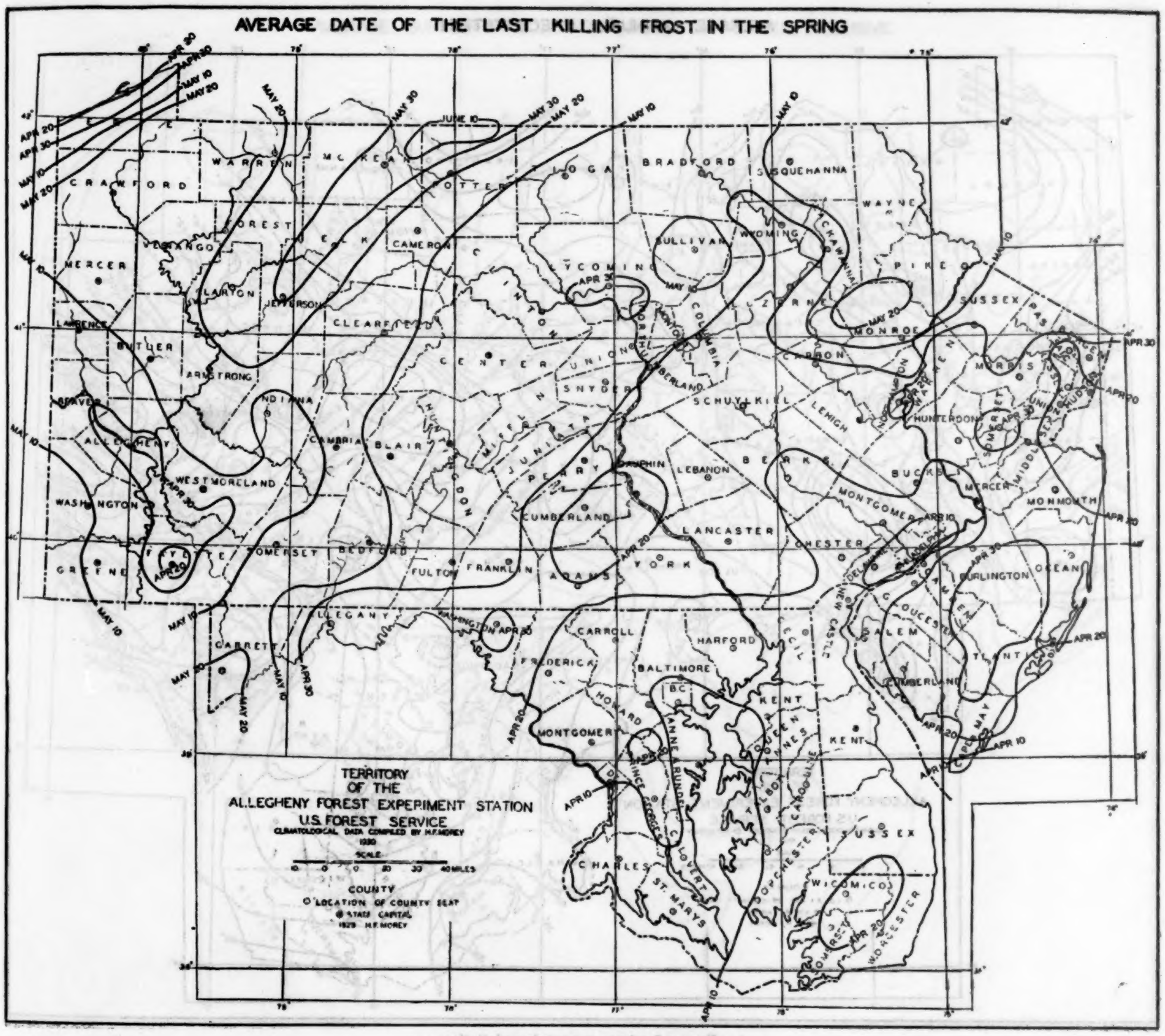

FIGURE 6.—Average date of last killing frost in spring

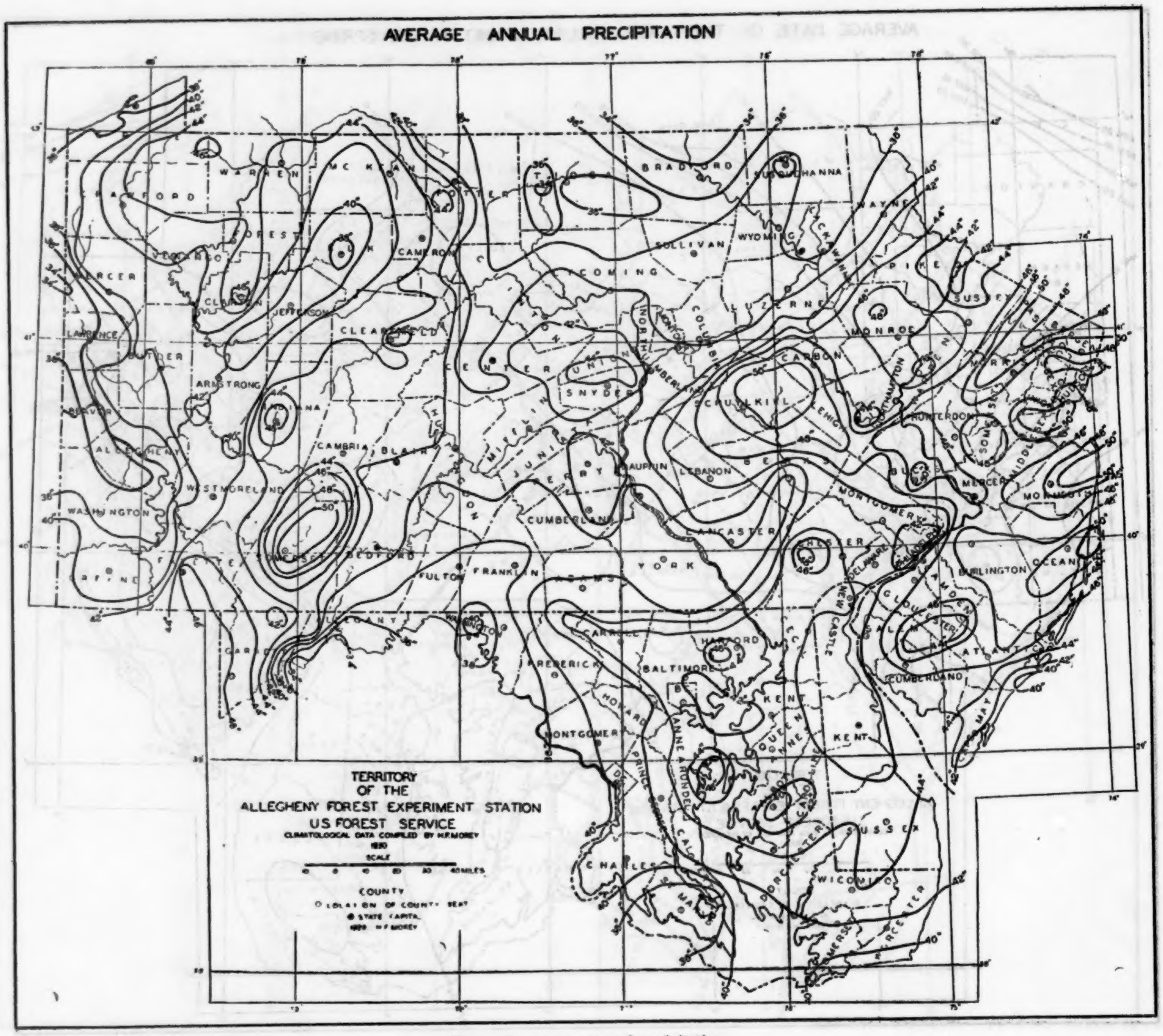

FIGURE 7.—Average annual precipitation

FIGURE 8.—Average summer precipitation

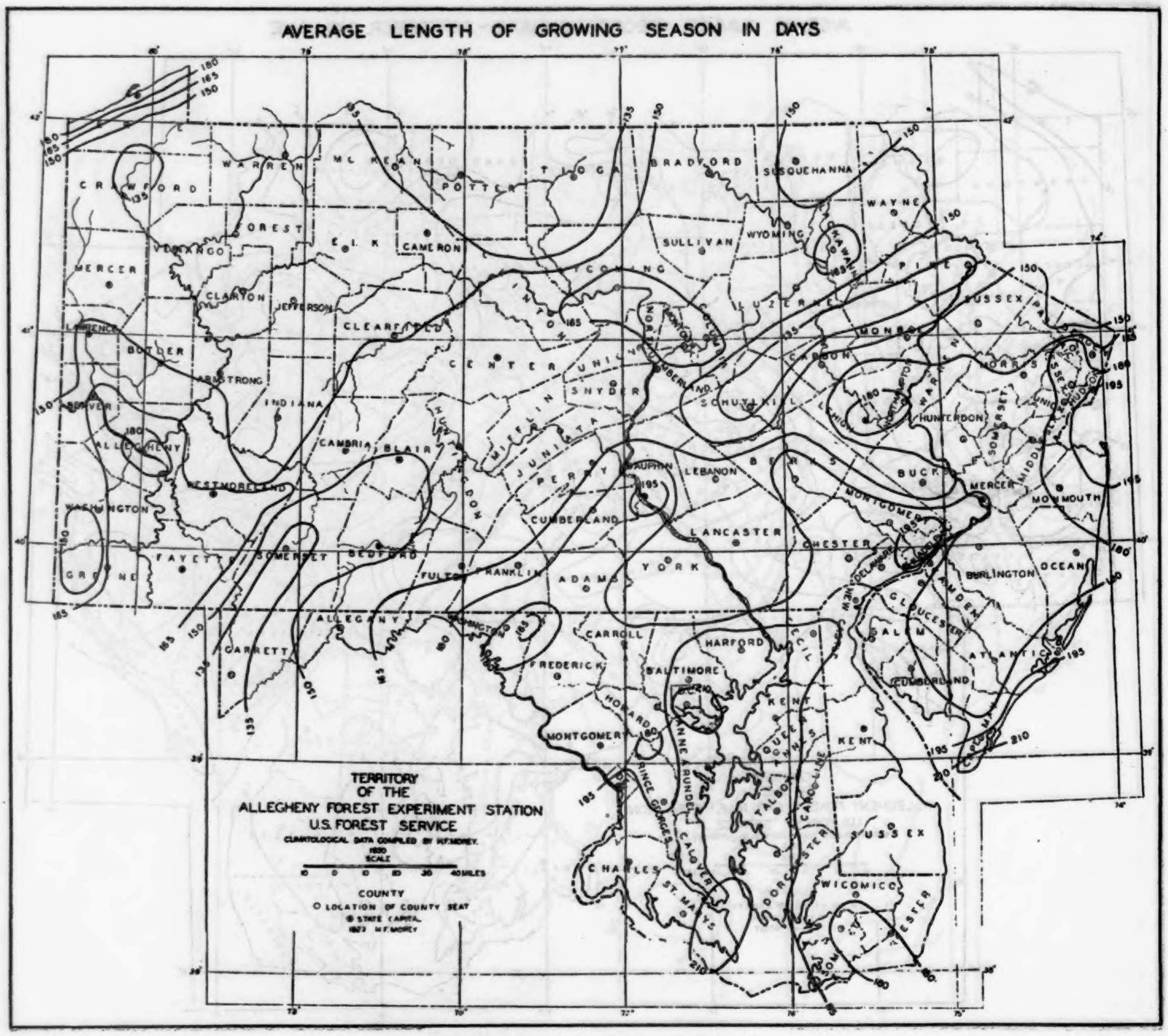

FIGURE 9.—Average length of growing season

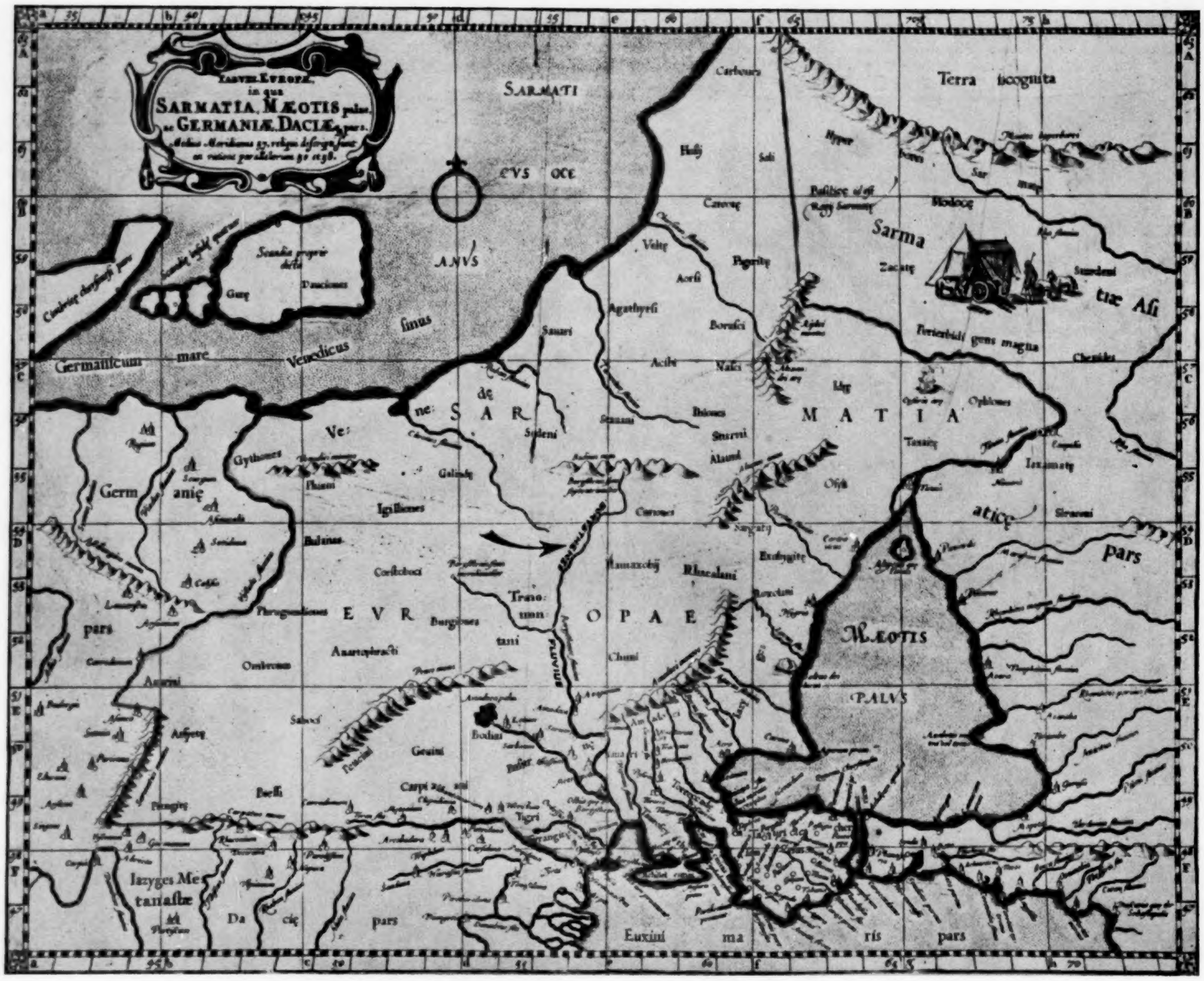

FIGURE 1.—Ptolemy's map, A. D. 150, showing Dnieper River (Borysthenes)

THE FLOW OF THE DNIEPER RIVER

By A. STREIFF, C. E.

[Jackson, Mich., January 29, 1931]

The Dnieper is the third largest river on the European continent. It was well known in antiquity, as shown on Ptolemy's map from his Geographica, A. D. 150. (Fig. 1.) The ancient Greeks named the great stream Borysthenes, after a Greek city located near the mouth on the north shore of the Euxine (Black Sea), a colony of Miletus in Asia Minor. Named Danapris by the Romans, Uzi-Uzu by the Turks, Eksi by the Tartars, Lerene by Contarini (1437), and Luosen by Baptista di Genoa (1514), its great drainage basin has been the stage of momentous scenes in history. Napoleon's armies perished while crossing the Beresina, one of its tributaries.

At present one of the great power stations of the world is under construction on this river by the Moscow Government, in consultation with Col. Hugh L. Cooper, builder of the Muscle Shoals and other large power dams. The dam is located in 47° 49′ north latitude and 35° 8′ east longitude. The backwater curve extends over a distance of 150 kilometers upstream. This great work is based on an exhaustive study made by Professor Alexandrov (1) from which the following data are taken.

The drainage area of the Dnieper above the rapids is 460,000 square kilometers. The average rainfall on the drainage basin is 540 millimeters (21.3 inches) per year. The average yearly run-off is 110 millimeters (4.3 inches) over a 40-year period, or 20.2 per cent of the rainfall. The mean annual temperature is 8.6 C. Snow cover is usually insignificant, hence the soil freezes to about 1.7 meters in depth.

The whole drainage area is practically level; near the lower reaches the river breaks through the granites and gneisses of ancient proterozoic formation and drops about 37 meters over a length of 150 kilometers.

The discharges of the Dnieper in the rapids are recorded at the long-established gaging station, Lotsmanskaja Kamenka, situated between the upper extremities of the rapids and the mouth of the Samara River. Daily discharges were computed for 49 years and special attention was given to the discharge under ice cover. These were analyzed as shown in Figure 2.

In this graph the discharge is resolved into the Clough cycle and a residual; the sum of both is equal to the original hydrograph.

It may be seen that the Clough cycle averages 28.5 months, or closely equal to the average value evaluated by Mr. Clough (2). This cycle varies the flow from 100 to 900 cubic meters per second between maximum and minimum of the cycle. Subtracting the Clough cycle from the hydrograph, the residual curve is obtained, which shows some remarkable characteristics.

The Wolf (11-year) cycle is at once plainly visible, and apparently culminates during the maxima of the Wolf numbers. Superimposed on this Wolf cycle is the Horton cycle of 5.5 to 6 years, so-called after R. E. Horton, who first discovered this cycle in stream flow in the year 1898 (3). The maxima and minima of the Horton cycle coincide with the maxima and minima of the Wolf numbers in a remarkable manner.

In its correlations with the Wolf numbers the chart compares very favorably with the records from the Great Lakes region in North America. The maxima of flow agree with both the maxima and minima of the Wolf numbers with neither lead nor lag, constituting the best example of this relation which the writer thus far has found.

The watershed is part of the great plains of Russia, and this confirms that the above-named relations are very pronounced in the continental plains, but show greater dispersion in mountainous regions. The flow of the Danube River near Florisdorf, draining the Austrian and Bavarian Alps, does not show a marked correlation. It seems that the presence of mountain chains has a tendency to disturb the general circulation of the atmosphere, and with it the sequence of precipitation and run-off. Also on the North American Continent do the flow records show the same characteristics.

The difference between the maxima and minima of the Wolf and Horton cycles (combined) is as much as 1,000 cubic meters per second. The flow during maxima is up to 80 per cent greater than the flow during minima.

Here again the vast difference between meteorological and hydrometric data is demonstrated. The difference

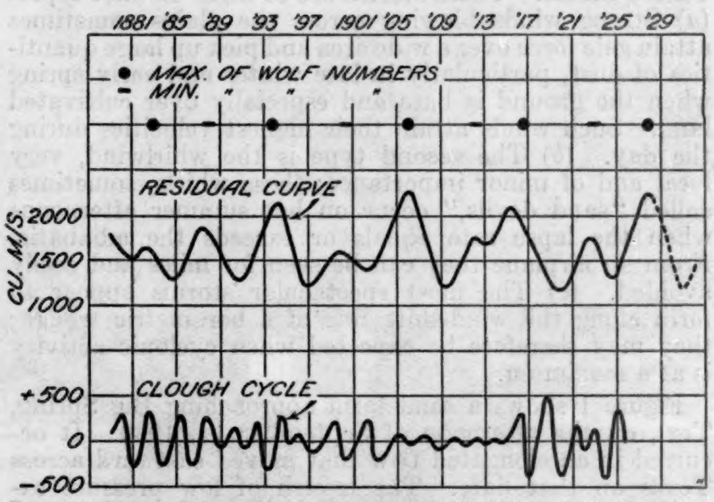

FIGURE 2—Flow of Dnieper River. From data furnished by Professor Alexandrov; Dnieprostroy project

in temperature due to the Wolf cycle is less than 1° C. (4), but the flow of this river varies as much as 80 per cent due to some unknown agency apparently in unison with the Wolf cycle (5).

As to the prognostication of future flow, it may be seen that 1931 should be a dry year on the Dnieper. The exact period of 22.6 years, or Brückner cycle (5) is here between minima fairly well confirmed in the stream flow. The distances between the minima of flow of the residual curve are 22, 24, 22, 23, 22 years, average 22.6 years. This should bring the next minimum in 1931. The low river stages will be favorable for the completion of the great Dnieprostroy dam and powerplant.

In explanation of the name Brückner cycle for the 22.6-year period, whereas it usually is supposed to have a length of 35 years, it may be referred to a previous article in the October, 1929 issue of the MONTHLY WEATHER REVIEW.

More can be concluded from the data shown as to future expectations. The next maximum will probably occur in 1935, and a high maximum in 1940. The amplitude of the Brückner cycle (not shown) is estimated at 350 cubic meters per second. Referring to Figure 3,

page 408 (5) the mean flow should reach a level toward the period 1945–1950 which may be 500 cubic meters per second greater than the present long-term average. The increase in the general mean of 1,600 cubic meters per second would amount to as much as 31 per cent. This latter estimate is necessarily uncertain and depends on the expectation that the "secular" cycle will repeat itself in the future with similar amplitudes as in the past. Accurate records are too short to conclude this with the same degree of probability as is possible in the case of the Horton cycle.

Thus the great Borysthenes of the anicent Greeks demonstrates the apparently close relations between variations in streamflow and the solar cycle. The records on which the above investigation is based were obtained by courtesy of Mlle. T. Maretsky, chief hydrologist, Nijne Dnieper, Moscow, Union of Socialist Soviet Republics.

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SANDSTORMS IN TEXAS

By JOHN A. RILEY

[Weather Bureau, Dallas, Tex.]

Large volumes of sand and dust are occasionally raised by the wind in dry weather over the western plains of the United States. These storms are of three distinct types: (*a*) Strong winds blowing across the plains sometimes attain gale force over a wide area and pick up large quantities of dust, particularly in late winter and early spring when the ground is bare and especially over cultivated land. Such winds attain their highest velocities during the day. (*b*) The second type is the whirlwind, very local and of minor importance; these whirls, sometimes called "sand devils," occur on hot summer afternoons when the lapse rate equals or exceeds the adiabatic. From an airplane they can be seen for miles and easily avoided. (*c*) The most spectacular storms appear to form along the wind-shift line of a barometric trough; they may therefore be expected when cyclonic activity is at a maximum.

Figure 1 shows a sandstorm approaching Big Spring, Tex., on the afternoon of September 14, 1930. It occurred in an elongated LOW that moved eastward across Texas on that date. The trough of low pressure extended at least from the Rio Grande Valley to northern Kansas. At 10 a. m. (ninetieth meridian time) there was a moderate sandstorm at Abilene, with a 20-mile south wind, and thunderstorms were occurring near Wichita Falls, Tex., Oklahoma City, Okla., and Springfield, Mo. At 1 p. m. there were fresh southerly winds from central Texas to Kansas and moderate northerly winds in the Panhandle and west Texas. At 4 p. m. Amarillo reported "moderate sand storm since 1 p. m.," and thunderstorm activity continued in the northern end of the trough, in Missouri. At 7 p. m. scattered thunderstorms were reported from the middle Rio Grande Valley to Kansas and Missouri.

The exact time of the Big Spring storm is not known, but judging from the shadows cast by the sun in Figure 1, it was approaching from a westerly direction at about 4 p. m. The sun was obscured in the second exposure and it was getting much darker in the third, due to the approach of the wall of dust.

Typical of the dry atmospheric conditions in west Texas, the temperature at 7 p. m. at El Paso was 86 and the dew point, 17; at Amarillo, 78 and 35, and at Abilene, 94 and 34. These conditions give rise to "dry squalls" in the semiarid plains of the West—a sudden shift of the wind through 90° or more generally from a southwesterly to a northwesterly direction. The speed of the wind in some of these dry squalls at times reaches gale force and is very gusty. In more humid regions these wind shifts are accompanied by thunderstorms and line squalls.

While the dry squalls do not usually equal in violence the line squalls of humid regions they are always very turbulent and at times violent. Except for the dust they may be practically invisible to the pilot in the air. Pilot J. G. Ingram relates that a few years ago he was flying across a wind shift in west Texas, when the ship dropped a thousand feet and was then carried up above its previous level, accompanied by violent turbulence. Pilot Homer Rader, flying between Dallas and El Paso, passed over a dry wind shift in west Texas late in 1930. From an altitude of 5,000 feet the ship settled slowly at first and then ran into a really violent windstorm, without rain or clouds. The ship was carried up 1,500 to 2,000 feet and dropped a like amount. The air was so rough that control of the ship was at times taken from him, and to relieve the strain the ship was allowed partly to adjust itself to the shock of the variable movements of the air.

Severe sandstorms for more than a short time are unusual, and flights are seldom canceled because of them, for, although the visibility may be zero at times, the dust comes in waves with the gusts of wind, and during the lulls the visibility improves enough for flight.

At times the sand drifts along the ground like drifting snow obscuring the ground but not rising to any great extent. Dust enough to interfere with visibility occasionally rises to 10,000 feet or higher, but it is more likely to be below 6,000 feet so that the pilot can climb above it. At other times the dust rises in columns like cumulus clouds and the pilot can fly around it.

The downward draft of a strong wind blowing across a mountain range often has a focus where it strikes the ground in the lee of the mountain, raising a layer of dust as well as making landing dangerous on account of the currents which are extremely variable in direction and force.

The following notes on sandstorms are furnished by Mr. W. H. Green, Weather Bureau official at Abilene, Tex.

> Most of our sandstorms occur with moderately high westerly winds, being rather severe when the wind reaches 33 miles or above. They seem to be most severe when the wind is from west-northwest. High winds from other directions sometimes cause considerable dust but usually precede thunderstorms and are therefore of short duration.
>
> The severity of the sandstorm depends to a very great extent on whether or not the ground is bare or covered with vegetation

FIGURE 1.—Sand storm approaching Big Spring, Tex. Photo by Bradshaw

even considerably more than on the current rainfall. We are not bothered much with sandstorms when the rainfall is normal or above and reasonably well distributed (some exceptions, however), while we occasionally have rather severe sand or dust storms a few hours after a heavy local rain.

The extent of the sandstorm is probably about the same as the extent of the high winds and the bare ground. I have personally seen much worse sandstorms on the plains of Texas, around Plainview, than I have seen in this vicinity; and Abilene people, who have occasion to be in El Paso at the same time that we have a sandstorm in this vicinity, occasionally come back and report that "New Mexico and Arizona both passed through El Paso the day before."

The visibility in a sandstorm varies, of course, with the intensity: In extreme cases it is perhaps not over 100 feet for a few minutes at a time, 300 feet for 30 minutes to an hour, not much over a quarter mile for 2 or 3 hours, and perhaps one-half mile for 4 or 5 hours. The most severe sandstorms occur in the day time, and are sometimes rather severe from about 9 or 10 a. m. to about 7 or 8 p. m.

Most of the sandstorms occur during February, March, and April, these months usually being comparatively dry, until after the middle of April, and the ground usually being bare or almost so, especially that in cultivation, until about the 1st of May, except an occasional year when considerable small grain is planted.

The Big Spring sandstorm bears a striking resemblance, as was pointed out by Prof. A. J. Henry, to the haboobs of the Egyptian Sudan, a photograph of which was reproduced in the Quarterly Journal of the Royal Meteorological Society January, 1925, with an account by L. J. Sutton. Sutton states that the haboob is a dense mass of whirling sand usually accompanied by a strong wind, but he does not clearly distinguish it from other sandstorms. Col. H. G. Lyons, commenting on Sutton's paper, suggests the similarity between haboobs and line-squalls. The haboobs he had experienced appeared as a front of violent upward and downward currents, in which the most striking feature was a mass of dust often thick enough to cause extreme darkness. Lyons thought the term should not include very strong dust-carrying storm, but be limited to circular storms which occur during periods of atmospheric instability. Haboobs in Nubia, he observes, usually come from the southeast and as they pass the wind veers round quickly to northwest, the sky clears and it is definitely colder.

Similar conditions have been noted by pilots in west Texas; shortly after the worst of a sandstorm had passed a cold layer of air near the ground was found to be overrun by a warm layer at about a thousand feet. It appears, therefore, that there is more than a superficial resemblance between the haboob and the Big Spring storm.

THE FOREST FIRE-WEATHER SERVICE IN THE LAKE STATES

By J. R. LLOYD [1]

[Weather Bureau, Chicago, Ill.]

It is doubtful if the average person grasps the enormity of the waste that has been, and is still being caused, in our great forests, which form a large portion of our northern woodlands. In order to acquire a true conception of the situation it is necessary for one to travel through the forests, noting the extent of the areas burned over and the damage that has been done, and to study forest fire statistics.

While no fires of really great extent have occurred in the Lake States in late years, the great Minnesota fire of October 12, 1918, stands out as an example of what might happen again if it were not for the eternal vigilance of the fire protection organizations; and there are times, when weather conditions go against them, that they are almost helpless. This great conflagration was the result of several factors operating in unison. The summer of 1918 in Minnesota was dry and warm, causing the grasses and other small vegetation on the forest floor to dry out and die much earlier than usual. This was followed by a dry autumn, which increased the fire hazard tremendously. Minnesota has much swamp land, and most of the swamps are filled with peat. There are more than 5,000,000 acres of peat land in Minnesota, of which a large portion had been drained prior to 1918.

Therefore, when the drouth of that year developed these peat lands dried out and became the chief source of trouble. Fire in peat is exceedingly difficult to extinguish. Some peat fires have been known to burn from one summer to another, even under a heavy covering of snow during the intervening winter. It so happened in 1918 that the State Forest Service of Minnesota lacked sufficient funds to meet this emergency, due largely to political dissension among State officials and legislators. This was exceedingly unfortunate. Many small fires were started in the peat lands that were not extinguished because of this lack of funds and personnel. These fires smouldered along until there came a day, October 12, with clear sky, low relative humidity, mild temperature and, fresh southwest winds. Then these smouldering fires spread, picked up momentum, merged into one great fire—the greatest of record in this country—and swept on, destroying nearly every living thing in its path. It traveled at great speed, and created winds powerful enough to pull up by the roots large trees. It swept over nearly a million acres in one afternoon and the early part of the following night, snuffed out the lives of nearly 1,000 human beings, killed thousands of domestic and game animals and birds, and destroyed probably $75,000,000 worth of forests and property. The city of Duluth had a very narrow escape, being saved principally by a high range of hills in the rear that parallel the shores of the lake and the bay. This great conflagration is mentioned as an example of what can happen in the northern woodlands when weather conditions are just right.

Since weather conditions play a major rôle in forest fire protection and suppression, it therefore follows that if the forest protective organizations know what to expect in weather for even a day or two in advance that they will be in a position to act on a given situation to better advantage. Therefore, the fire-weather service in the Lake States was created to supply a demand, voiced by the fire protection organizations, for weather forecasts and other weather information that might help them in combatting this red scourge that has cost so many millions of dollars in money, and taken so many thousands of lives of human beings and denizens of the wild.

The project was started in Minnesota during the summer of 1926. From a modest beginning in 1926 the service has been gradually expanded. It was organized in Wis-

[1] In charge fire-weather project in the Lake States.

consin and upper Michigan in 1927 and 1928, and in lower Michigan in 1928. It now covers all of the principal forested lands in the three States, embracing nearly 60,000,000 acres. There are now 33 substations scattered throughout the fire-weather district. These substations are the eyes of the service, so to speak. Most of them are located at the headquarters offices of the State district rangers and wardens, and are about 40 to 60 miles apart from each other. Each station is equipped with a maximum and a minimum thermometer, a rain gage, a sling psychrometer, and an anemometer, and some of them are supplied with hygrographs. Observations are made three times a day, at 8 a. m., noon, and 5 p. m., central standard time, and are usually begun about the 1st of April and continued until about the 31st of October. The headquarters of the service is now located at Chicago, having been transferred from Duluth, Minn., on November 1, 1928.

During the fire season about 25 selected fire-weather stations telegraph reports to Chicago once a day, immediately following the 8 a. m. observation. These reports show what kind of weather has prevailed during the 24-hour period ending at 8 a. m., and give an estimate made by the observer of the degree of fire hazard existing in the forest in the vicinity of the station. The data from these reports are entered on a special outline map, and give a good birds-eye view of conditions existing throughout the district. Particular attention is given to the relative humidity, in connection with the temperature, sunshine, wind movement and rainfall. All these elements are factors in evaporation, and consequently in fire hazard. It may be readily seen that estimation of the degree of fire hazard existing at a given time, and an estimate of what it will be one or two days in advance is a very complicated problem. Not only do the weather factors have to be considered, but thought has to be given to the condition of the forest fuels, which are gradually changing throughout the season, and which are many and variable in kind and character. No single instrument has yet been devised that will give a reliable estimate of the degree of existing hazard. The duff hygrometer, an instrument devised to measure the moisture content of duff and litter on the forest floor has not proved to be successful. The evaporimeter does not give a good index either, since the evaporation that is measured by it is produced in an artificial manner that is not comparable to the manner in which evaporation takes place from forest fuels. Therefore, estimation of existing hazard is largely a matter of personal judgment formed after considering all of the factors involved, and opinions may vary considerably between two or more individuals on a given condition.

When the daily fire-weather reports are received and entered on the map and it is indicated that fire-weather warnings are in order, warnings are made and dispatched to the men in the field as soon as possible, usually about 9.30 a. m. A typical warning as issued for the field would read about as follows:

> Fair Friday and probably Saturday; temperature near 90°; humidity 25 to 35 per cent; gentle to moderate southerly winds becoming southwest by Saturday; high to extreme hazard.

Warnings are telegraphed to sections only where the fire hazard so warrants, and as a rule, the State district rangers and wardens, the superintendents of the State forests, and the supervisors of the national forests are the persons that receive them. Warnings are telegraphed to about 55 points scattered throughout the forested area. The men that receive these warnings by telegraph relay them by telephone to their principal assistants in the field, so that all of the men that have charge of fire protection and suppression work are supplied with this information. The warnings also are broadcast by radio from several stations in or near the forested regions, and are printed in several newspapers as well.

Although particular attention has been given to relative humidity in determining fire hazard, it is doubtful if relative humidity is a more important factor in this connection than temperature. It seems that pioneers in fire-weather investigation, even up to the present time, have overstressed the importance of relative humidity in proportion to temperature in estimating fire hazard. The writer has recently performed some research work in this connection to determine the relationship of relative humidity and temperature to the inception of forest fires. This investigation disclosed the fact that relative humidity and temperature bear practically equal weight on fire hazard, and that these two factors are embodied in the depression of the wet-bulb thermometer of a whirled psychrometer in such a manner that the fire hazard seems to be directly proportional to the change in the wet-bulb depression, other factors being equal. This throws into discard the theory that fire hazard is proportional to the change in depression of the dew point, an idea that seemed to be substantiated by preliminary investigation.

Inception of forest fires, when plotted on a graph against relative humidity, temperature and depression of the wet bulb, have a well defined range. Out of 2,000 fires plotted it was found that only one fire started with temperature below 39°, and that none started when the relative humidity was above 80 per cent. It is also a fact that not a single fire broke out when the wet-bulb depression was below 4°, and that all the fires had started by the time a wet-bulb depression of 26° was reached. The investigation indicated that the wet-bulb depression scale may be divided arbitrarily into rather definite zones of hazard. However, these zones of hazard, being predicated on average conditions, would naturally not apply all of the time. Higher than ordinary wind velocities and periods of drouth would tend to augment the hazard, while on the other hand, appreciable rainfall would tend to lower it, resulting in a shifting of the zones to higher and lower positions on the wet-bulb depression scale.

The fire-weather forecasts are based largely upon the daily manuscript weather maps and the auxiliary pressure change and temperature change charts. There are several types of weather maps that may give rise to high fire hazard, but the most striking type is the one with a HIGH centered west or northwest of the fire-weather district and moving southeastward, followed by a LOW that moves eastward along the Canadian boundary or a little to the northward thereof. This type of map usually gives the lowest relative humidity, and is quite common in spring, April and May, when usually the lowest relative humidity readings occur. The relative humidity usually runs low within the confines of these HIGHS as they pass over the fire-weather district, and when they move in such a manner as to place the center of the HIGHS over the middle Mississippi and the Ohio valleys during the daytime, they often produce extremely low relative humidity readings on the days when such circumstances occur. Relative humidity readings as low as 11 per cent have been noted in May in Minnesota, and readings in the twenties are not at all uncommon in all three States under such conditions. These low relative humidity values are undoubtedly brought about by pressure conditions that allow rapid night radiation of temperature, followed the next day by a rapid rise, thus producing a great range in temperature during the day, and consequently unusually low relative

humidity. Diurnal ranges in temperature of 45° to 50° have been noted in the forested areas of the north when favorable pressure distribution prevails.

As a rule, more forest fires occur in the spring than during any other season of the year, due to the fact that there is then a plentiful supply of dead vegetation on the ground; the days are long, allowing much sunshine; the deciduous trees are leafless or nearly so, allowing the sunshine to strike the forest fuels and dry them out quickly; the relative humidity is at its lowest; and finally, there is usually plenty of wind movement to help dry out the fuels and fan the flames, once a fire is started. However, the year of 1930 proved an exception to the rule in this respect. The long, hot drouth in August and September caused an unusually severe summer fire season that was much more severe than the preceding spring fire season. Michigan and Wisconsin experienced this year one of the worst summer fire seasons, if not the worst, in the history of their respective forest services. The fall fire season is short, as a rule, due to the fact that the days are short and the nights are cold. The relative humidity may be low during the middle of the day in autumn, but only for a few hours, and it is nearly always high then at night, which, with the low night temperatures, is sufficient to either extinguish most ordinary fires, or to check them to such an extent that they may be easily extinguished. The forest rangers say that a cold night is worth the services of 100 or more men in putting out a big fire. While the fall fire season is short and usually less severe than the spring season, it is a singular fact that most of the great conflagrations of the north have occurred in autumn. However, these great fires have always followed drouthy summers.

Fire protection in the Lake States is a problem that has to do largely with care exercised by man; therefore, to a large degree, it is an educational problem. Ninety-nine per cent of all forest fires that occur in the Lake States are man-caused, either directly or indirectly. The other one per cent is caused by lightning. There are areas in the Western States where 35 to 50 per cent of the fires are caused by lightning, thereby creating a very difficult problem; but the number of lightning fires in the Lake States is so small that lightning is given no consideration in the forecasts. The number of fires that occur in the Lake States annually is very large, but of course varies considerably from year to year, depending on the weather. During 1929 about 6,500 fires occurred in these States, burning over about 450,000 acres. This year's totals are not yet available, but it appears that there were probably as many as 7,500 fires that burned over more than a half million acres. Such is the heavy toll exacted by fire, man's greatest friend, it has been said, but perhaps at the same time his greatest enemy.

AIRPLANE LANDINGS IN GUSTY SURFACE WINDS

By PAUL A. MILLER

[Weather Bureau Airport Station, Bolling Field, D. C.]

When surface winds are moving at velocities over 25 miles per hour considerable difficulty is often encountered in landing an airplane. During such times the air currents moving along the surface are considerably retarded by friction, while a few feet above the surface the flow is unhindered. This results in a turbulent condition near the surface, which makes a treacherous landing support for an airfoil passing through it, especially if the wind is gusty.

An airplane landing in still air is glided down within about 2 feet of the ground, where it is leveled off. Flying along level with the motor cut off, it soon loses speed and support. However, it is kept from falling by gradually raising the nose, which presents the airfoil surfaces, at a larger and larger angle to the air, with consequent very gradually decreasing support, but rapidly lessening speed. Presently the speed is so low that the airfoils, no matter what their angle, can no longer fully support the plane, and it settles slowly to the ground in a 3-point landing, i. e., the wheels and the tailskid touch at the same instant. During this time, since the air is still, it has not been necessary to correct for the lateral or longitudinal position of the plane.

How different the case where a strong, gusty surface wind is present. Long experience then becomes necessary to make a good landing, for the plane is buffeted, raised, or dropped unceasingly, and the pilot must have the delicate touch and feel to anticipate and overcome the hazards before they place the plane in a perilous position. If the plane is kept in the proper position to make a landing in still air, the landing will be extremely hazardous. For, if the plane is glided down at normal speed, it will encounter gusts and vertical currents which will raise it, drop it, or throw it over on one wing. Also when leveling off to land, the pilot does not dare to lose much flying speed, for he must have positive control to overcome gusts, and this can be maintained only with an excess of flying speed. For instance, an ordinary mail plane, well loaded, usually lands with an air speed of about 55 miles per hour. Now, if a 30-mile wind is blowing, the plane will land with a ground speed of about 25 miles per hour. Let us assume that the pilot intends to land in the manner used in still air and that he is leveled off and just ready to touch the surface. A sudden gust raises the wind velocity temporarily to 40 miles per hour, giving the plane an actual air speed of 65 miles per hour, and at the large angle the airfoils now present, the plane will suddenly be lifted to a height of 10 or 15 feet. The gust passes, leaving the plane stalled, as the gust has also taken a part of the plane's forward speed. Now, if the pilot has not quickly speeded up the engine and put the nose down in order to gain air speed the plane will actually fall to the ground, with considerable damage to it and a bad shaking up or worse for the pilot. Complicate this situation during landing with the fact that there may be rather violent vertical currents present, which will throw the plane over on one wing or raise or drop it suddenly, and it will readily be seen that under conditions of gusty winds a landing can not be made in the normal manner with any degree of assurance.

Under such conditions, most pilots of experience bring the plane in with an excess of flying speed, probably 10 or 15 miles per hour over the normal speed. Then if the plane is thrown into an abnormal position, the controls have a quick action and the plane can be righted quickly. However, with this excess of flying speed, the plane will not settle to the ground, but must actually be flown down until the wheels touch the surface, it being understood, of course, that the excess speed is gained by nosing down at a steeper angle than normally rather than by the use of the engine. When the wheels touch, the tail is kept up in flying position, which causes the airfoils to present a small

angle of attack to sudden gusts. The plane is kept in the position until considerable speed is lost and the tail drops of its own accord due to lack of support. The weight of the plane and its lower speed then make it practically independent of further gusts.

It can be seen from the foregoing that a knowledge of the prevalence of gusty winds at landing areas is of vital necessity if safe landings are to be made. From a meteorological viewpoint, the occurrence of winds that will cause dangerous landing conditions can be forecast with considerable accuracy. While this is being done more and more as time goes on, there is still room for considerable improvement in the knowledge of local areas where landings are dangerous in gusty weather. Surveys of various terminal airports to determine the areas of maximum turbulence in various winds are becoming a necessity with the increase of passenger flying now occurring. A survey of this kind would give the meteorologist the knowledge necessary to advise the pilot in the air of the gusty condition prevalent and the best landing area on the airport. This advice would be especially helpful at night when landing passenger planes, and would constitute another safety factor to aviation in general.

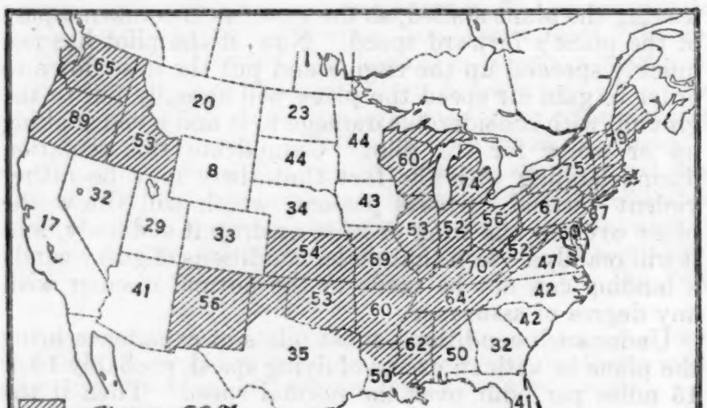
As an illustration of the value of being forewarned of the prevalence of such conditions, the following instance is cited. During January, 1929, a large area of low pressure passed over the middle Western States followed by a rather intense northwestern high. This pressure distribution caused extremely high, gusty surface winds along the Kansas City-Chicago Airway. Winds aloft were also extremely strong, reaching velocities of over 70 miles per hour. A mail pilot took off at Kansas City for the afternoon trip to Chicago, carrying one passenger. The pilot found when he was aloft that it was necessary to crab the plane into the northwest wind at an angle of over 45° in order to remain on the course. The air was so rough that at times they would drop 300 feet and then be driven upward the same amount, both actions being so violent that the wings vibrated alarmingly. The landing lights in the wings were shaken loose and hung in the air stream, banging against the wing with such force as to threaten to tear the tips off. After a 4-hour fight they arrived over Moline Airport, where red landing flares had been put out to advise them that a landing was dangerous. However, the ship was almost out of fuel and a landing had to be made. Wind velocties, as shown by the airport anemometer, were regularly over 40 miles per hour and during gusts reached as high as 58 miles per hour. Through the forethought of the field manager, an ambulance and fire truck had been summoned to take care of any contingencies that might arise in attempting to make a landing. The pilot circled the field and came into the wind, where he found that it was necessay to keep the engine almost wide open to make progress against it. He nosed the ship down and gradually lost altitude. When nearing the fence a sudden gust struck the ship, forcing one wing down until it was almost vertical, but it had sufficient air speed to overcome this and was quickly brought to normal. The pilot then actually flew the ship to the ground, where with its slow ground speed it stopped almost at once. He experienced great difficulty in taxying up to the shelter of a hangar, as with the least access of speed the ship wanted to take off again. However, his previous knowledge of the landing conditions prevailing, combined with his long experience, had enabled him to make a safe landing where none was thought possible.

RELATIONS BETWEEN WINTER TEMPERATURE AND PRECIPITATION

By THOMAS ARTHUR BLAIR

[Weather Bureau, Lincoln, Nebr., Jan. 2, 1931]

What is the relation between winter temperature and winter precipitation in the United States? The lowest temperatures of winter generally occur with fair weather near the center of an anticyclone. The heaviest winter precipitation usually falls with mild or moderate temperatures. May we assume, then, that as a rule warm winters are wet and cold winters dry. The following table and chart are an attempt to answer that question.



The data were taken from the tables of comparative State means printed in the annual summaries of climatological data by each section center. They are for the three winter months, December, January, and February, and only those years are counted in which the average temperature departure was $\pm 2°$ F, or more. Table I, in which the States are arranged by regions, gives for each State or section the number of times departures of temperature and precipitation were of like sign and of unlike sign and the percentage of the total having like signs. The percentages are entered by States on the chart, and areas where the percentage is greater than 50 are shaded.

In the shaded areas warm and wet winters are likely to occur together and cold and dry winters together. The presumption that the winters will occur in this way is strongest in Oregon, Michigan, New York, and New England. In these States three-fourths of the winters averaging 2° F. warmer or colder than normal have precipitation departures in the same sense. On the other hand, the chances are better than even that warm winters will be dry and cold winters wet in the South Atlantic States, Texas, the western upper Mississippi Valley, the Missouri Valley, the Rocky Mountain region from Colorado northward, the southern Plateau States, and California. They occur in this association nine times out of 10 in Wyoming, more than three times out of four in California, Montana, and North Dakota, and two times out of three in Nevada, Utah, Colorado, and Georgia.

The area of percentages above 50, which extends northeastward from New Mexico to the Great Lakes

and New England, is obviously associated with the winter cyclones which appear in the southwest and move northeastward. Rain and warm weather occur in their path and snow and cold weather to the northwest. At Dubuque, Iowa, it was found [1] that precipitation in winter occurs more frequently with falling temperature than with rising. In the Plateau and Pacific States the well-known relation between precipitation and the latitudinal position of cyclones as they approach the coast is evident, especially in the marked contrast between Oregon and California. Northern LOWS are attended by warm and wet weather in Oregon and warm and dry in California; southern LOWS by cool and dry weather in Oregon and cool and wet in California. These statements are, of course, incomplete and partial and serve only to illustrate the relations suggested by the chart. It is beyond the scope of this note to enter into a discussion of the conditions under which winter precipitation occurs in the various States and sections of the country. The sole object has been to compile and present the facts of record, expressed in State averages, showing the relationship between winter temperature and precipitation departures.

TABLE 1.—*Number of times winter temperature and precipitation departures were of like and unlike signs. Only those winters were counted in which the average temperature departure for the three months, December, January, and February, was ±2° F. or more*

States	Departures of—		Percentage having like signs
	Like signs	Unlike signs	
North Atlantic:			
New England	15	4	79
New York	15	5	75
Pennsylvania	14	7	67
New Jersey	12	6	67
Maryland and Delaware	8	8	50
Sums	64	30	68
South Atlantic:			
Virginia	9	10	47
North Carolina	8	11	42
South Carolina	8	11	42
Georgia	7	15	32
Florida	7	10	41
Sums	39	57	41

[1] T. A. Blair, Local Forecast Studies—Winter Precipitation, M. W. R., 52: 79-85.

TABLE 1.—*Number of times winter temperature and precipitation departures were of like and unlike signs. Only those winters were counted in which the average temperature departure for the three months, December, January, and February, was ±2° F. or more*—Continued

States	Departures of—		Percentage having like signs
	Like signs	Unlike signs	
Lake region, Ohio Valley, and eastern Mississippi Valley:			
Michigan	14	5	74
West Virginia	11	10	52
Ohio	15	12	56
Indiana	13	12	52
Kentucky	14	6	70
Wisconsin	12	8	60
Illinois	19	17	53
Tennessee	16	9	64
Alabama	12	12	50
Mississippi	13	8	62
Sums	139	99	58
West Gulf:			
Louisiana	9	9	50
Texas	6	11	35
Sums	15	20	43
Central Plains and middle Mississippi Valley:			
Missouri	18	8	69
Kansas	13	11	54
Oklahoma	9	8	53
Arkansas	9	6	60
Sums	49	33	60
Western upper Mississippi Valley, Missouri Valley, and Rocky Mountain:			
Iowa	18	24	43
Minnesota	11	14	44
North Dakota	5	17	23
South Dakota	11	14	44
Nebraksa	12	23	34
New Mexico	10	8	56
Colorado	6	12	33
Wyoming	1	11	8
Montana	4	16	20
Idaho	9	8	53
Sums	87	147	37
South Plateau and south Pacific:			
Nevada	6	13	32
Utah	5	12	29
Arizona	7	10	41
California	1	5	17
Sums	19	40	32
North Pacific:			
Oregon	17	2	89
Washington	13	7	65
Sums	30	9	77

INTERPOLATION OF RAINFALL DATA BY THE METHOD OF CORRELATION

ERIC R. MILLER

[Weather Bureau, Madison, Wis.]

The object of this paper is to apply to a climatological problem a method already well established in other sciences. Suppose that it is wished to interpolate from observations at near-by stations the monthly rainfall at a station where observations have been taken previously. I shall use the symbol Y to refer to rainfalls at the first, X, at the others, y and x to refer to deviations from the mean rainfalls.

Think of a "scatter diagram" each point of which represents the simultaneous rainfalls, X measured on a horizontal scale, Y on a vertical scale. The "regression line" of the statistician (6, p. 120) has the property that the sum of the squares of the distances of the dots of the scatter diagram measured parallel to the Y axis from the regression line, is less than from any other line. Hence, under a least-squares criterion of approximation, the regression line is the "best" representation of the relation between Y and X for all amounts of rain. The following remarks will be restricted to straight regression lines, but the fitting of curved regression lines is also practiced.

The formation of the regression equation, representing algebraically the regression line, involves calculation of the standard deviations of the observed X's and Y's, and their coefficient of correlation. Concise examples of this are given in books on statistics (8, p. 178–179), (6, p. 123) and the calculation is easily carried out with the aid of Crelle's Tables (1).

Horton (3) has given some correlation coefficients calculating from 12 months taken at random. In order to ascertain the effect of change of season upon the correlation coefficient, I have calculated it for the 32 years (1897 1928) rainfall at Waupaca and Pine River, Wis. (14 miles apart), for January, when practically all rain falls in "general" storms for May, the wettest month, with many heavy thunderstorms, and for August, a month characterized by very local rain and drought.

The results were:

	January	May	August
Correlation coefficient	0.94±0.014	0.92±0.018	0.89±0.025
Average rainfall:			
Waupaca	1.15	4.06	3.65
Pine River	1.08	4.06	3.40
Standard deviation:			
Waupaca	.82	2.08	1.66
Pine River	.70	2.48	2.03

From these statistics the regression equations, expressing rainfalls at Waupaca in terms of rainfall at Pine River, are:

In deviation from the mean:

January .... $y=1.10\ x$
May .... $y=\ .77\ x$
August .... $y=\ .73\ x$

In total rainfall:

January .... $Y=1.10\ X-\ .03$
May .... $Y=\ .77\ X-\ .93$
August .... $Y=\ .73\ X-1.17$

The effect of increasing distance between stations upon the correlation coefficient is shown by the following table of correlation with May rainfall at Waupaca:

	Pine River	Grand River Locks	Portage	Beloit
	X_1	X_2	X_3	X_4
Distance from Waupaca, miles	14	40	58	126
Correlation coefficient	0.92±0.018	0.76±0.05	0.73±0.55	0.40±0.10
Mean rainfall	4.06	4.24	3.93	3.63
Standard deviation	2.48	2.20	1.87	1.79

The regression equations, expressing Waupaca rainfall in terms of the rainfalls at each of these four stations, are:

(The variables are the deviations in inches from the mean)

Distance

14 miles .... $y=0.77\ x_1$
40 miles .... $y=\ .72\ x_2$
58 miles .... $y=\ .81\ x_3$
126 miles .... $y=\ .46\ x_4$

(The variables are the monthly rainfalls in inches)

14 miles .... $Y=0.77\ X_1+\ .93$
40 miles .... $Y=\ .72\ X_2+1.01$
58 miles .... $Y=\ .81\ X_3+\ .88$
126 miles .... $Y=\ .46\ X_4+2.37$

The decrease of the correlation coefficient per mile amounts to 0.005 or 0.006.

Calculation of regression equations for two or more control stations is more complicated, but numerical examples that can be followed by any novice are given in the books referred to at the end of this article (6, p. 145), (4, p. 205), (2, p. 136–138). The labor is greatly reduced by the use of Miner's Tables (5) or Kelley's Alignment Chart (4, back cover) and Chiò's method of evaluating determinants (7, p. 71.)

As examples of such regression equations I have calculated three involving the three control stations, Pine River (14 miles south of Waupaca), New London (18 miles east), and Stevens Point (26 miles northwest.) The following table contains the statistics on which these calculations were based:

Correlation coefficients of stations in heading, with stations at left.—Monthly rainfalls for May, **32** *years,* **1897–1928**

	Waupaca	Pine River	New London	Stevens Point
	Y	X^1	X^2	X^3
Pine River	0.92±0.018			
New London	.85± .033	0.89±0.025		
Stevens Point	.92± .018	.88± .027	0.88±0.027	
Mean rainfall	4.06	4.06	4.08	3.80
Standard deviation	2.08	2.48	2.10	1.95

Regression equations—

(1) In deviation from the means:

$$y=+0.57\ x_1-0.10\ x_2+0.50\ x_3$$
$$y=+\ .80\ x_1+\ .14\ x_2$$
$$y=+\ .52\ x_1+\ .46\ x_3$$

(2) In monthly rainfalls, inches:

$$Y=+0.48\ X_1-0.10\ X_2+0.48\ X_3+.70$$
$$Y=+\ .68\ X_1+\ .14\ X_2+\ .75$$
$$Y=+\ .44\ X_1+\ .49\ X_3+\ .42$$

It will be noted that the smaller correlation between New London and Waupaca than between New London and the other controls, although the latter are farther away, has a marked effect in diminishing the New London coefficient in these multiple regression equations.

The labor of these calculations of multiple regression equations does not increase in proportion, when a number of equations are derived for different stations, based on the same controls, because the same intermediate coefficients are used again and again in the different relations.

In closing, I wish to acknowledge the cheerful assistance of Junior Observer Alfred L. Lorenz, who calculated all of the total correlations for me.

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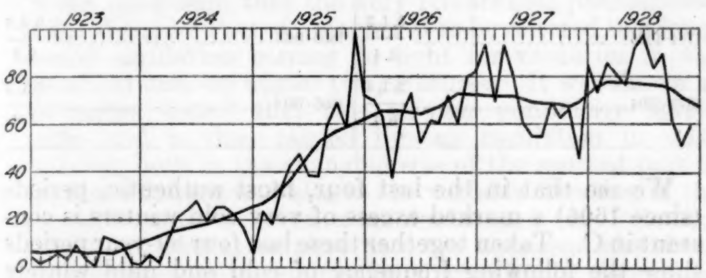
SMOOTHED MONTHLY MEANS OF SUN-SPOT RELATIVE NUMBERS, 1920–1929, INCLUSIVE [1]

[Furnished through the courtesy of Prof. W. Brunner, who made the observations and computations]

[Federal Astronomical Observatory, Zurich, Switzerland, January, 30, 1930]

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1920	46.8	43.2	40.3	39.4	38.7	37.9	36.8	34.9	32.1	31.0	31.3	30.6	36.9
1921	31.0	31.7	31.1	29.0	27.3	26.5	25.3	24.4	25.5	25.8	24.3	22.5	27.0
1922	20.1	18.1	16.9	15.8	14.9	14.4	13.9	12.6	9.4	7.1	6.7	6.6	13.0
1923	6.4	5.9	6.0	6.6	6.9	6.4	5.6	5.6	5.7	5.8	6.8	8.1	6.3
1924	9.8	11.6	12.9	14.0	15.1	16.1	16.9	17.9	19.3	20.9	22.6	24.5	16.8
1925	25.9	27.1	29.3	32.6	35.9	40.9	47.2	51.8	55.6	57.7	58.9	60.9	43.7
1926	62.6	64.1	65.1	65.2	65.4	64.7	64.3	65.7	66.9	69.5	72.4	72.4	66.5
1927	72.0	71.8	71.7	71.7	71.6	70.5	69.1	68.4	68.3	68.4	67.7	69.0	70.0
1928	72.1	75.1	77.3	78.1	77.3	77.2	77.1	76.1	74.2	71.6	69.2	67.7	74.5
1929	66.2	64.3	61.3	58.6	59.6	63.0	64.8	64.0	62.8	61.1	60.6	57.5	62.0



Recent epochs of maximum and minimum: Minimum, 1913.6, 1923.6; maximum, 1917.6, and probably about the middle of 1928.

SAN FRANCISCO FORECAST CENTER ADOPTS NEW BASE CHART

On January 29 the San Francisco district forecast center adopted a new base chart for use in charting weather reports received twice daily at that forecast center.

The new chart covers the Pacific Ocean from about the one hundred and eightieth meridian of west longitude eastward to and across the North American Continent to the Atlantic Ocean and in a north-south direction from about the thirty-fifth parallel of north latitude to the Arctic Ocean. The use of this base chart marks a great improvement in the facilities for charting weather reports from the Pacific and for the Canadian Northwest, including Alaska.—*A. J. H.*

TORNADO IN WARREN COUNTY, N. C., JANUARY 5, 1931 [2]

By CLARENCE E. SKILLMAN

[Weather Bureau, Raleigh, N. C.]

The storm, described as a large funnel-shaped cloud with a heavy roaring sound, struck first at about 4.35 p. m. on the farm of Mr. J. W. Bishop, 3 miles west of Wise in the northwest part of the county. It destroyed a tobacco barn and packhouse and moved half a mile northeast to where Jim Dunston, colored, lived in a log cabin in a grove of large oak trees. In a course about 100 yards wide it uprooted or twisted off practically every tree in the yard and destroyed completely the house and all outbuildings, killing Jim Dunston and three children outright, one son, 23 years old, dying next day in a hospital. A mile further on it dipped down to destroy a stable and two barns.

Three miles to the northeast, with occasional signs between, it struck in the neighborhood of the Warren County Training School for colored children. Here it struck Locust Grove colored church at the right side of its path, moving it 50 feet north and wrecking it. The colored Christian Church on the left of the path was blown away entirely, except for the floor and foundation. The roof is nowhere to be seen.

At the school there were several frame buildings grouped around a large frame 2-story building in the center. One building on the right, or southeast, side was not materially injured. The main building, directly in the path of the storm, evidently too substantial to be torn down, was moved north off its foundation and twisted beyond repair. Part of the roof on the south side was torn off. A girls' dormitory at the rear of the main building was wrecked, leaving only the floor and part of the partitions standing. About 20 girls were in this building at the time, most of them remaining there. Of those who ran out into the storm, one was struck and killed by a flying piece of timber and another, a teacher, sustained two broken ribs. None of those in the building were injured. A garage and implement shelter in the same line were demolished and the machinery damaged. A large poultry yard lying partly in the path of the storm was about half destroyed and 75 hens were taken up and carried several hundred yards and found dead. Another building at the left was only slightly injured. The top of a large pine standing at the right side of the path of the storm was broken off about 50 feet from the ground and carried 70 yards north and driven 10 feet into the corner of the main frame building.

In all, six people were killed and the property loss is estimated at $35,000.

[1] For summary of preceding years, see MONTHLY WEATHER REVIEW, August, 1920, vol. 48, p. 460.

[2] At 8 a. m. seventy-fifth meridian time January 5, 1931, a cyclonic storm was centered over southeastern Tennessee with central pressure down to 29.30 inches; in the next few hours it moved almost due northeast and its center must have passed on the left of Warren County at a probable distance of 50 to 75 miles. Tornadoes in January, although not unknown, are unusual.—*Editor.*

PERIODIC OSCILLATIONS OF TEMPERATURE

By the late DR. C. EASTON

[Scheveningen, Netherlands]

[Meteorologische Zeitschrift, 1929, p. 171]

Relative to the interesting work of A. Wagner on the yearly oscillation of temperature in Europe in the last decades (Meteorologische Zeitschrift, 45 p. 364), I should like to make the following remarks:

Prof. A. Wagner finds that "the frequency * * * of mild winters in middle Europe in the last decades is such a striking phenomenon that it has been noticed not only by meteorologists, but also by everyone in the uninitiated class who experienced the severe winters at the close of the preceding century." The winters of 1917 (1916–17), 1922, and 1924, however, were certainly not mild; the first-named even ranks with severe winters and it would probably be better to take into consideration only the decade 1906–1916. Prof. A. Wagner compares the years 1886–1895 with the years 1911–1920, that is, the periods in which the temperature oscillation was greatest and least, respectively. As it appears to me, Prof. A. Wagner correctly concludes from his studies that one does not arrive at an explanation of this peculiarity through any secondary cause whatever; he believes that it is rather to be referred to a strengthening of the general circulation "now continuing for decades."

It is very worthy of note that diminished yearly amplitude of temperature in Europe, as Prof. A. Wagner determines it for the next to the last decade, is manifest at intervals of 89 years in the historic data on winter weather. With diminished yearly oscillation there is associated a decided decrease in the frequency of very severe winters and, often, a high frequency of mild winters.

The last-named phenomenon was very evident in the next to the last decade; the winters of 1910, 1911, 1912(?), 1913(?), 1914, 1915, and 1916(?) showed a mean temperature in excess of the normal, that is, at least for western Europe.[1] This feature is so decided that in Petermann's Mitteilungen (1905, Heft 8) I ventured to predict that "there appears certainly warranted the inference of a period of extraordinarily few cold winters, at whose beginning we probably find ourselves at this time (1905)."

That earlier investigation, which was based on historical data relative to severe winters in western and middle Europe—mainly in the Alpine region and its vicinity [2]—collected by Wilhelm Köppen, drew attention to the presence of one or more rather long periods that were to be considered as multiple lengths of the well-known sun-spot period of approximately 11 years and that came to light both in the activity of the sun and in the oscillations of winter temperature in Europe; an 89-year period (8 by 11⅛ years) had been pointed out most plainly, especially in a very rare occurrence of severe winters toward the end of this long period.[3]

The historical material was much improved by myself through the addition of data on mild winters and by the limitation of the lines of argument to the climatic province of western Europe. (See, among other references, Peterm. Mitt., LXIII, 1917 and, especially, Les Hivers Dans l'Europe Occidentale; Etude Statistique et Historique Sur Leur Température. Tableaux Comparatifs, Notices Historiques, et Bibliographie. Leyden. E. J. Brill. 1928.) From my last compilation I take the following Table 1. In it the period 1205–1916 is divided into eight 89-year periods, and each period is subdivided into divisions of 22, 23, 22, and 22 years; here only the last two parts are cited (C: 1250–1271, and D: 1272–1293, etc.). The number of very severe, severe, and cold winters is given for each subdivision (above), and the number of moderate and mild winters (below). For example, we find for 1272–1293 winters noted as follows: Very severe, 0; severe, 3; cold, 3; moderate, 0; and mild, 2.[4]

In this it is to be borne in mind (1) that the data relative to mild winters are always very indefinite and very often unreliable; and (2) that the period is certainly somewhat variable and therefore the rises and falls do not fit exactly into the mathematical limits here given; thus, for example, the winter of 1895 (1894–1895) belongs without doubt in the preceding subdivision C; for the present free choice is to be avoided only by a strict mathematical division.

[1] For the climatic region of western Europe I found the temperature coefficients 65, 57, 74, 77, 55, 65, 74 (normal=50). Details in my work, Les Hivers Dans l'Europe Occidentales. Leyden, 1928, p. 208.

[2] Wl. Köppen. Über merkwürdige Perioden der Witterung usw., Zeitschr. d. Österreich. Ges. f. Meteorol., Bd. XVI. 1881. After my work of the year 1917 was published Professor Köppen discovered an 89-year period in his material. Compare Ann. d. Hydr. u. marit. Meteorol., XXV, 11, 1917 and Meteorol. Zeitschr. XXXV, 3, 4.

[3] C. Easton. Zur Periodizität der solaren und klimatischen Schwankungen, Peterm. Mitt. 1905, Heft 8. Compare Versl. Kon. Akad. v. Wetensch. Amsterdam, Nov. 26, 1904, June 24, 1905.

[4] It is evident that the older data are less complete than the later. In addition the terms "severe" and "mild" are here determined scientifically and do not always agree with the popular understanding. For the elaboration of the historical data see Les Hivers, introduction and, especially, pp. 166 and 200.

TABLE 1.—*Frequency of cold and mild winters in 22-year periods*

C		D	
1250–1271	0, 1, 5 / 0, 4	1272–1293	0, 3, 3 / 0, 2
1339–1360	0, 2, 5 / 0, 1	1361–1382	1, 3, 2 / 3, 0
1428–1449	1, 2, 1 / 0, 3	1450–1471	0, 3, 2 / 0, 4
1517–1538	0, 0, 4 / 2, 5	1539–1560	0, 3, 2 / 0, 2
1606–1627	2, 1, 4 / 2, 3	1628–1649	0, 0, 5 / 0, 3
1695–1716	1, 2, 3 / 4, 5	1717–1738	0, 1, 3 / 1, 1
1784–1805	3, 1, 3 / 3, 4	1806–1827	0, 2, 4 / 2, 3
1873–1894	2, 1, 4 / 0, 4	1895–1916	0, 1, 2 / 1, 6

We see that in the last four, most authentic, periods (since 1606) a marked excess of very cold winters is constant in C. Taken together these last four 89-year periods show the following frequency of cold and mild winters (totals in parentheses):

In Table 2 there comes to view still more plainly the marked temperature oscillation in C and the moderate number of cold and very cold winters in D. (D gives the summation of the periods 1628–1649, 1717–1738, 1806–1827, and 1895–1916.)

It is, however, very evident that the simple summation of very cold and very mild winters without regard to the plus or minus departure must give a good picture of the greater or lesser temperature oscillation. We find for all eight periods since 1205:

TABLE 2.—*Frequency of cold and mild winters in four 89-year periods since 1561*

Subdivision A	5, 10, 11 (26) / 4, 10 (14)	Subdivision C	8, 5, 14 (27) / 9, 16 (25)
Subdivision B	1, 9, 11 (21) / 2, 19 (21)	Subdivision D	0, 4, 14 (18) / 4, 13 (17)

TABLE 3.—*Total number of winters that were very cold or very mild*

Subdivision	1205–1916	1561–1916
A	43	24
B	31	30
C	39	30
D	25	8

For convenience, Table 4 in the original text has been combined with Table 3.

The great amplitude in C and the moderate amplitude in D comes to view very plainly, especially in the best authenticated data (period 1561–1916).

It is also possible to determine on an absolute scale, and with rather good approximation, the intensity of the temperature oscillation in C and D by means of "tem-

perature coefficients" obtained by critical comparison of historic and modern data. (See Les Hivers, p. 10 ff.) The departures of the coefficients from the normal of 50 (as given on p. 200 of the work mentioned) are found totaled in Table 4.[1]

Relative to the last result, 247 and 203, see remark on the winter of 1895.

TABLE 4.—*Totals of the departures of the temperature coefficients*

C		D	
1606–1627	306	1628–1649	138
1695–1716	388	1717–1738	135
1784–1805	336	1806–1827	222
1873–1894	247	1395–1916	203

The above table is numbered 5 in the original text.

These statistical data appear to indicate the correctness of the conclusion that the very remarkable phenomenon pointed out by Prof. A. Wagner is to be referred to a long-period oscillation coming to light for centuries in the historical data on winter temperatures. It was shown at an earlier date[2] that this 89-year periodicity agrees with—and is thus caused by—an oscillation in solar activity, both in the changing size of the spotted part of the sun's sufrace and also in the variable duration of the period of time between a minimum and the following maximum; the agreement becomes apparent also from the coincidence of an unusual cold wave at the close of the eighteenth century with an accelerated and intensified sunspot activity[3] at the same time. In conclusion I should like to add that I consider this 89-year periodicity not as a single period, but as a resonance or interference phenomenon at the coincidence of probably numerous independent periods, of which, however, no individual one has any considerable amplitude.

It would be interesting to test whether the 89-year oscillation comes more plainly into view in middle Eurpoe (as here for western Europe) in my newly revised data (Les hivers).—*Translated by W. W. Reed.*

COMMENTS ON THE INFLUENCE OF VEGETATION ON STREAMFLOW

By FRANCIS E. COBB, President and State Forester

[North Dakota School of Forestry, Bottineau, N. Dak., February 7, 1931]

I am much interested in the article[4] by Harry B. Humphrey and B. C. Kadel in regard to the influence of trees on stream discharge.

A small stream, Oak Creek, flows along the border of our campus, originating in springs located about 4 or 5 miles in the foothills of the Turtle Mountains. This is an intermittent creek and it is very common for this stream to discontinue flowing during the summer. In dry springs it may not flow after June. Sometimes it continues as late as August and occasionally runs throughout the year. However, it is commonly noticed that in the summer when it does not flow it always begins flowing as far down as we are located in the fall after the leaves have fallen from the trees. Sometimes it starts to flow even earlier than this. The article in question would lead me to believe that the growth of trees, which is quite heavy along its entire course to where we are located, have a great deal to do with the discontinuance of the flow during their growing period. It has often been wondered why after a dry summer it should begin in the fall even before the freezing of the ground, and this is apparently an explanation.

An article also in this same issue in regard to the passing of the mirage from the Weather Bureau at Dodge City, Kans., is also of interest.

We are a cooperative observer of the Weather Bureau at Bismarck and are naturally interested in all phenomena relative to weather conditions. Southeast of this town on clear, warm days during the entire summer a mirage lies, giving the appearance of a very large lake with tall trees on the banks and looks as though the farm houses in that section were entirely flooded, except for their upper stories This entire territory is in crop and apparently no difference appears whether the crop is growing or harvested.

I merely note this as a matter of interest inasmuch as here it does not depend on whether the prairie is bare or in crop.

ARCTIC WEATHER STATIONS

By C. F. TALMAN

Just as, in the Southern Hemisphere, an outpost for weather observations maintained by the Argentine Government at Laurie Island, in the subantarctic South Orkneys, is operated by a small party who spend a year in complete isolation—being then replaced by another party—so in the far north the Russian Government has a number of weather stations whose staffs are relieved annually. The most northerly is the one established in Franz Josef Land in 1929. These arctic stations, like the one at Laurie Island, are equipped with radio.

Last summer the ice breaker *Sedov* visited the station in Franz Josef Land, where the seven members of the staff were found in good health. They were replaced by a new staff of 10 men and 1 woman. The latter, the wife of the director, is to conduct biological investigations.

From Franz Josef Land the *Sedov* proceeded through ice fields to the archipelago north of the Taimyr Peninsula formerly known as Emperor Nicholas II Land but now called Severnaya Zemlya (Northern Land). Some previously unknown islands were discovered, including a group of small ones to which the name Kamenev Islands was given, and in one of these a new station was established, in latitude 79° 24′ north and longitude 91° 3′ east. Four men were left here, with provisions for three years.—*Why the Weather—Scientific Service (Inc.).*

LIGHTNING FROM A CLEAR SKY, JANUARY 20, 1931

By FRED MYERS

[Weather Bureau, Tatoosh Island, January 20, 1931]

At 4:17 a. m. a flash of lightning was observed overhead and slightly toward the north. The sky was clear with about 2 strato-cumulus clouds along the horizon from the southwest to the northwest. There were six or eight flashes from 4:17 a. m. to 4:32 a. m., no more being observed until 5:15 a. m. when a single flash occurred in about the same location as the others.

Light rain had been falling during the night, ending about 2:45 a. m., the sky clearing by 4 a. m., the stars were shining brightly and the clouds could be seen distinctly in the west. The lightning appeared to flash across the sky and not to the ground. No thunder followed the flashes. This is the first time lightning has occurred from a clear sky at this station as far as can be determined.

The wind was from the south about 23 miles per hour, the temperature 48°; the barometer 30.16 and humidity 92 per cent at 4:45 a. m. (120 meridian time).

[1] This is Table 5 in the original text.

[2] C. Easton. Peterm. Mitt. 1905 and Proceedings Kon. Akad. v. Wetensch. te Amsterdam, 4/5, 5/6, *Bd.* VII, VIII.

[3] Compare *Astronom. Mitt.*, R. Wolf and A. Wolfer. Zurich. A sunspot curve for 1745–1875 by Wilh. Myer is published in Das Weltgebäude, 1898, p. 295.

[4] See MONTHLY WEATHER REVIEW, October, 1930, vol. 58, p. 397, ff.

While only a few flashes were observed, the "howler"[1] on the composite telephone was very noisy, sounding like static on a radio. This was probably due to lightning near Port Angeles. The Navy radio operator said that he had not noticed any lightning, but that the static had been bad all night.

[1] The composite phones "ring" by a buzzer arrangement which is heard through the "howler." This is nothing more than a receiver with a small horn to amplify the sound. It is connected to the line so that any noise on the line is heard through the "howler."

CLIMATOLOGICAL SUMMARY FOR CHILE NOVEMBER AND DECEMBER, 1930

By J. Bustos Navarrete

[Observatorio del Salto, Santiago, Chile]

November.—Atmospheric circulation was less active than in October. Important depressions crossed the extreme southern region in the following periods: 8th-10th, 18th-20th, 24th-26th, and 27th-29th. Anticyclones, all moving from southern Chile toward Argentina, were charted from 4th to 7th, 12th to 17th, and 24th to 26th.

December.—Despite the advance of the season the atmospheric circulation continued active, ending in a severe storm in the south near the summer solstice. Well defined depressions crossed the southern region during the periods 2d-3d, 10th-13th, and 18th-21st. Anticyclones showed but little intensity, the one with greatest development being that of the 22d-26th moving from southern Chile toward northeastern Argentina and Brazil.—*Translated by W. W. Reed.*

FRANKLIN G. TINGLEY, 1871-1931

Franklin Ginn Tingley was born October 8, 1871, at Marion, Ind., and died at Hyattsville, Md., January 26, 1931. He was educated at the public schools of his native town and at Purdue University, from which he was graduated with the degree of bachelor of civil engineering. He was appointed to the Weather Bureau July 16, 1898, and was one of the pioneer observers of the West Indian weather service organized by the bureau during the Spanish-American War primarily for the protection of the American fleet in Caribbean waters. After a brief period of instruction at Washington, he served at Kingston, Jamaica, as assistant to W. B. Stockman, who was in charge of the West Indian service. When the headquarters of the service were moved from Kingston to Habana in January, 1899, Tingley remained at Kingston in charge of the station. In June, 1899, he was transferred to Habana. In August, 1899, on account of illness, he was recalled to the United States, and served successively at the Atlanta, Wilmington, and Jacksonville stations of the Weather Bureau. In November, 1901, he was assigned to the central office at Washington, where for many years he was connected with the administrative branch of the bureau.

Meanwhile he became deeply interested in certain scientific problems, especially as bearing upon the question of extending the period of weather forecasts. In June, 1916, he was assigned to the climatological division to pursue his studies of forecasting and also to take charge of the marine section of that division. On April 1, 1920, the marine section was made a separate division, and Tingley became its chief. He served in this capacity up to the time of his death. The marine work of the bureau was greatly enlarged under his capable direction, including, among its more recent developments, a comprehensive revision of wind-roses for the Pilot Charts and the beginnings of a far-reaching study of surface-water temperatures.

Modest, gentle, and unselfish to an extraordinary degree, Tingley won the affection of everybody with whom he came in contact. His death was a grievous personal loss to his late colleagues and associates.—*C. F. T.*

BIBLIOGRAPHY

C. Fitzhugh Talman, in charge of Library

RECENT ADDITIONS

The following have been selected from among the titles of books recently received as representing those most likely to be useful to Weather Bureau officials in their meteorological work and studies:

Ashbel, Dob.
Die Niederschlagsverhältnisse im südlichen Libanon, in Palästina und im nördlichen Sinai. Berlin. 1930. 79 p. figs. 23 cm. (Inaug.-Dissert. Friedrich-Wilhelms-Univ. Berlin.)

Clyde, George D.
Establishing snow courses and making snow surveys. Logan. n. d. 16 p. illus. 23 cm. (Utah agric. exper. sta. Circ. 91. Dec. 1930.)

Gallé, P. H.
Klimatologie van den Indischen Oceaan. V. Neerslag. VI. Frequentie van luchtdrukkingen en stormachtige winden. VII. Tropische cyclonen. Amsterdam. n. d. 31 p. illus. plate (fold.). 24 cm. (K. Ned. met. inst. no. 102. Med. en verh. 29c.)

Harmer, Paul M.
Prevention of wind injury to crops on muck land. East Lansing. n. d. 8 p. illus. 23½ cm. (Agric. exper. sta. Mich. state coll. Soils sec. Circ. bull. no. 103. March, 1927.)

Hölcke, Theodor.
Der Einfluss der Höhenlage auf die Niederschläge in Thüringen. Weimar. (1930. 47 p. figs. map (fold.). 21 cm. (Mitt. der Thür. Landeswett. Heft 2.)

International commission for the study of clouds.
International atlas of clouds and of states of the sky. Abridged edition for the use of observers. Paris. 1930. ii, 41 p. 41 plates. 32 cm.

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Kochergin, V.
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Results of evaporation studies conducted at the Scripps institution of oceanography and the California institute of technology. Berkeley. 1930. p. 401–415. 27½ cm. (Bull. Scripps inst. ocean., Tech. ser., v. 2, no. 11.)

Pettersson, Vilhelm I., & Pettersson, Otto.
Cartes synoptiques trimestrielles donnant la température et la salinité de l'eau de surface de l'océan Atlantique Nord. n. p. n. d. [3 p.] fig. plates (fold.) 35 cm.

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Wetter und Verkehrswesen. v. p. figs. 30 cm. (Die Reichsbahn. nr. 37–39. Jahrg. 1929. 11, 18, 25 Sept.)

Welter, L.
Note sur l'organisation de la protection météorologique de la navigation aérienne en Afrique Occidentale Française. [Paris. 1930.] 8 p. figs. 25½ cm. (Bull. du comm d'études hist. et scient. de l'Afrique Occident. Franç. Année 1930. T. 13.)

SOLAR OBSERVATIONS

SOLAR RADIATION MEASUREMENTS, JANUARY, 1931

By HERBERT H. KIMBALL

At Washington, D. C., Madison, Wis., and Lincoln, Nebr., the Weather Bureau has installed Marvin pyrheliometers with which, when the sky is free from clouds, measurements of the intensity of direct solar radiation are obtained.

At Washington the measurements are made on the campus of the American University, about 5½ miles northwest of the United States Capitol, 3 miles northwest of the Central Office of the Weather Bureau, and 1½ miles northwest of the United States Naval Observatory. There are no manufacturing establishments within a radius of about 3 miles, but the suburb about the university is rapidly building up, principally with detached houses. The pyrheliometer is exposed on a shelf outside a window, in the morning on the southeast side of the building and in the afternoon on the southwest side. At times, with southeast or east winds, city smoke is brought over the university. The pyrheliometer is at latitude 38° 56′ north, longitude 77° 05′ west, altitude 397 feet.

At Madison the pyrheliometer is installed in North Hall, University of Wisconsin, and exposed on a shelf outside a window facing east in the morning and west in the afternoon. North Hall is on a bluff in the upper campus, a short distance from the south shore of Lake Mendota. Most of the manufacturing plants are in the eastern part of the town, but railroad tracks and the heating plant of the university are to the Southwest. With a northwest wind the air is free from smoke, but with the wind from other directions considerable smoke is brought over the campus. The latitude of North Hall is 43° 05′ north, longitude 89° 23′ west, altitude 974 feet.

At Lincoln the pyrheliometer is exposed in the experiment station building, on the farm campus, State University Farm. It is 2½ miles northeast of the center of the business section of the city, but there is some smoke from buildings on the farm campus and from railroads and shops not far to the north. Under certain conditions the city smoke cloud covers the farm campus, but with a west to northwest wind the atmosphere is very clear. The latitude of the farm campus is 40° 50′ north, longitude 96° 41′ west, altitude of pyrheliometer above sea level 1,225 feet.

When observing, the pyrheliometer is exposed on a shelf outside a south dormer window.

Continuous records of the intensity of the solar radiation received on a horizontal surface, including that received diffusely from the sky, are obtained by the Weather Bureau at Madison, Wis., and Lincoln, Nebr., by means of Callendar pyrheliometers. The registers are installed in the rooms with the auxiliary apparatus used with the Marvin pyrheliometers, and the geographical coordinates for the two stations are as already given. The Callendar pyrheliometers are exposed on the roofs of the buildings occupied—at Madison at an elevation of 1,009 feet and at Lincoln of 1,250 feet above sea level. Both these pyrheliometers have practically unobstructed exposure to the sky down to the horizon in every direction.

A summary of continuous records obtained by means of a Callendar recording pyrheliometers is received each month for publication in the MONTHLY WEATHER REVIEW from Mr. O. J. Sieplein, director of the Belle Isle Observatory, University of Miami, Miami, Fla., at latitude 25° 41′ north, longitude 80° 12′ west, altitude but a few feet above sea level. A similar summary is received from the Scripps Institution of Oceanography, La Jolla, Calif., latitude 32° 50′ north, longitude 117° 15′ west, altitude 85 feet above sea level; but at this latter station a Weather Bureau thermoelectric pyrheliometer recording on an Engelhard microammeter is employed.

Records are also obtained at the American University, D. C., the Weather Bureau stations at Chicago, Ill., New York, N. Y., Pittsburgh, Pa., and Fresno, Calif., at Twin Falls, Idaho, through cooperation with the Bureau of Entomology, Department of Agriculture, and at Gainesville, Fla., through cooperation with the department of physics, University of Florida. Fresno and Gainesville employ Moll thermoelectric pyrheliometers, the former recording on an Engelhard, the latter on a Richard microammeter. The other stations employ the Weather Bureau type of thermoelectric pyrheliometers and Engelhard recording microammeters. In New York City the radiation apparatus is exposed at the New York Meteorological Observatory, Central Park, and in Chicago on the tower of Rosenwald Hall, on the University of Chicago campus.

Coordinates of these stations are as follows:

Station	Latitude	Longitude	Altitude
	° ′	° ′	*Feet*
Chicago, Ill	41 47 N.	87 35 W.	688
New York City	40 46 N.	73 58 W.	156
Pittsburgh	42 26 N.	80 00 W.	1114
Fresno	36 43 N.	119 49 W.	350
Twin Falls	42 29 N.	114 25 W.	4300
Gainesville	29 39 N.	82 21 W.	233

At Chicago the pyrheliometer is exposed to the south of the tower on which the wind instruments are exposed and which shades it from a part of the north sky. The same is true of the exposure in New York to a lesser extent and also at Fresno. At Washington the roof of the Chemical Laboratory, about 300 feet to the north, cuts off a small section of the sky near the horizon.

All pyrheliometers from which records are summarized in Tables 1 and 2 have been standardized by comparison with Marvin No. 3, except the Callendar instrument at Miami, which has a standardization certificate furnished by the English manufacturer. Quite probably this certificate gives radiation intensities in the Ångström scale, but I have been unable to obtain definite information on this point. Marvin No. 3 is checked with Smithsonian substandards from time to time through Smithsonian No. 1, which is owned by the Weather Bureau.

Table 1 shows that solar radiation intensities averaged above the normal intensity for January at Washington, D. C., and slightly below normal at Madison, Wis., and Lincoln, Nebr.

Table 2 shows an excess in the total solar radiation received on a horizontal surface directly from the sun and diffusely from the sky at all stations except Madison, for which there was a pronounced deficiency.

Skylight polarization measurements were obtained at Washington on five days and give a mean percentage of 56, with a maximum of 59 on the 2d and 13th. These are below the corresponding averages for Washington in January. No measurements were obtained at Madison during this month, as the ground was continuously covered with snow.

TABLE 1.—*Solor radiation intensities during January, 1931*

[Gram-calories per minute per square centimeter of normal surface]

Washington, D. C.

Date	Sun's zenith distance: 8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass: A. M.					P. M.				Local mean solar time
	e.	5.0	4.0	3.0	2.0	[1] 1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Jan. 2	1.96	0.98	1.10	1.22	1.38			1.27	1.11	0.98	2.06
Jan. 7	2.16	0.66	0.78		1.16			1.09			2.16
Jan. 9	2.26		0.63	0.78	0.98			0.90			2.87
Jan. 13	4.75				1.20						2.62
Jan. 15	1.24		1.10	1.21	1.31			1.11	0.98	0.75	1.52
Jan. 16	1.78		0.86	0.98							2.06
Jan. 17	3.45			1.07	1.26			1.08	0.94	0.82	3.45
Jan. 20	2.87		0.89					1.14	0.99	0.81	2.62
Jan. 22	1.12				1.06						1.52
Jan. 28	4.95			0.84	1.03		1.01				4.17
Jan. 30	3.30				0.97						2.36
Means		(0.82)	0.89	1.02	1.15		(1.01)	1.10	1.00	0.84	
Departures		+0.09	+0.04	+0.01	−0.08		−0.22	+0.06	+0.12	+0.04	

Madison, Wis.

Date	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
Jan. 3	2.26	0.76	1.00	1.09				1.14			3.63
Jan. 9	3.15	0.97	1.07	1.17				1.30			2.87
Jan. 16	2.87	0.76	0.90	1.06				1.10			3.45
Jan. 22	1.78							0.96			1.78
Jan. 26	2.36	0.94	1.11	1.17	1.40						2.87
Means		0.88	1.02	1.12	(1.40)			1.12			
Departures		−0.07	−0.03	−0.08	+0.04			−0.08			

Lincoln, Nebr.

Date	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
Jan. 2	3.45	0.93	0.99	1.12							3.63
Jan. 4	3.00							1.21	1.07	0.97	3.63
Jan. 5	2.49	1.05	1.17								3.00
Jan. 14	1.02	1.04	1.08								1.07
Jan. 15	1.88							1.11	0.98	0.86	3.00
Jan. 16	2.36							1.02	0.86	0.80	3.81
Jan. 21	2.26		1.07	1.17				1.14			3.63
Jan. 26	3.30	1.04	1.13	1.21	1.40						3.63
Jan. 28	3.30				1.36			1.14	1.04	0.93	4.57
Jan. 29	3.63		0.82	1.15	1.30						4.37
Jan. 31	3.45		1.02	1.20	1.39		1.38	1.22	1.11	1.00	3.15
Means		1.02	1.04	1.17	1.36		(1.38)	1.14	1.01	0.91	
Departures		+0.08	−0.01	−0.01	−0.01		−0.03	−0.03	−0.03	−0.01	

[1] Extrapolated.

TABLE 2.—*Total solar radiation (direct + diffuse) received on a horizontal surface*

[Gram calories per square centimeter]

Week beginning—	Washington	Madison	Lincoln	Chicago	New York	Twin Falls	Pittsburgh	Gainesville	Fresno	La Jolla	Miami
	Average daily totals										
1931	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Jan. 1	175	105	189	68	113	183	115	276	128	220	262
Jan. 8	168	119	232	98	137	152	93	239	211	237	233
Jan. 15	196	149	202	95	146	220	130	216	227	279	145
Jan. 22	172	162	235	121	138	224	166	296	212	261	223
	Departures from weekly normals										
Jan. 1	+21	−29	+4	−12	+9	+2	+26	−2	−15	−13	
Jan. 8	+14	−25	+40	+15	+34	−40	+1	−4	+45	+10	
Jan. 15	+37	−12	+1	−2	+34	+18	+18	−16	+35	+48	
Jan. 22	−7	−26	+12	+8	−2	+27	+42	+26	−21	+21	
Accumulated departures on Jan. 28	+455	−644	+399	+63	+525	+49	+609	+28	+308	+462	

POSITIONS AND AREAS OF SUN SPOTS

[Communicated by Capt. J. F. Hellweg, Superintendent United States Naval Observatory. Data furnished by Naval Observatory, in cooperation with Harvard, Yerkes, Perkins, and Mount Wilson Observatories. The differences of longitude are measured from central meridian, positive west. The north latitudes are plus. Areas are corrected for foreshortening and are expressed in millionths of sun's visible hemisphere. The total area, including spots and groups, is given for each day in the last column]

Date	Eastern standard civil time	Heliographic: Diff. long.	Longitude	Latitude	Area: Spot	Group	Total area for each day
1931	*h m*	°	°	°			
Jan. 1 (Naval Observatory)	11 14	No spots					
Jan. 2 (Naval Observatory)	11 18	No spots					
Jan. 3 (Naval Observatory)	11 49	No spots					
Jan. 4 (Naval Observatory)	11 4	−78.0	237.6	−18.0		62	62
Jan. 5 (Mount Wilson)	14 0	−65.0	235.8	−19.0		122	
		−51.0	249.8	−12.0	12		134
Jan. 6 (Mount Wilson)	13 15	−49.0	239.1	−19.0		129	
		−48.0	240.1	−10.0		5	134
Jan. 7 (Naval Observatory)	11 41	−35.0	240.8	−18.5		108	108
Jan. 8 (Naval Observatory)	11 41	−20.5	242.1	−19.5		77	77
Jan. 9 (Naval Observatory)	12 3	−9.0	240.2	−18.5		123	123
Jan. 10 (Naval Observatory)	11 49	+6.0	242.2	−19.0		62	62
Jan. 11 (Naval Observatory)	11 41	+18.0	241.1	−19.0		46	46
Jan. 12 (Mount Wilson)	14 10	+4.0	212.5	+8.0	20		
		+34.0	242.5	−19.0	32		52
Jan. 13 (Naval Observatory)	12 12	+19.0	215.5	+9.0		62	
		+45.0	241.5	−19.5	31		93
Jan. 14 (Naval Observatory)	13 12	+29.0	211.7	+7.0		123	
		+33.5	216.2	+7.0	46		169
Jan. 15 (Naval Observatory)	11 43	+40.0	210.4	+8.0		170	170
Jan. 16 (Naval Observatory)	14 14	+55.0	210.8	+8.5		463	463
Jan. 17 (Naval Observatory)	11 37	+67.5	211.6	+8.5		355	355
Jan. 18 (Mount Wilson)	13 25	−22.0	107.9	+5.0		71	
		+80.0	209.9	+8.0		337	408
Jan. 19 (Mount Wilson)	14 10	−70.0	46.4	+2.0	4		
		−5.0	111.4	+5.0		84	88
Jan. 20 (Naval Observatory)	11 54	−55.0	49.5	+2.0	19		
		+8.5	113.0	+6.5		123	142
Jan. 21 (Naval Observatory)	11 42	+20.0	111.4	+5.0		93	93
Jan. 22 (Naval Observatory)	13 18	+35.0	112.4	+6.5		154	154
Jan. 23 (Naval Observatory)	12 30	+9.0	74.6	+8.0	3		
		+48.0	113.6	+3.0		154	157
Jan. 24 (Naval Observatory)	12 43	+59.0	110.3	+5.0		139	139
Jan. 26 (Perkins Observatory)		No spots					
Jan. 27 (Naval Observatory)	11 19	No spots					
Jan. 28 (Naval Observatory)	11 21	+48.0	47.4	+3.0		31	31
Jan. 29 (Naval Observatory)	13 52	No spots					
Jan. 30 (Naval Observatory)	12 13	No spots					
Jan. 31 (Naval Observatory)	11 29	+10.0	329.9	+3.5	9		9
Mean daily area for January							109

AEROLOGICAL OBSERVATIONS

By L. T. SAMUELS

Free-air temperatures during January were exceptionally high at Ellendale, with the departures decreasing with increase in altitude. (See Table 1.) Positive temperature departures occurred also at Royal Center and in the lower levels at Broken Arrow. Elsewhere the departures were negative.

Free-air relative humidity departures were variable and of small magnitude at all stations. Those for vapor pressure were in agreement with the temperature departures.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during January, 1931*

TEMPERATURE (° C.)

Altitude *Meters* m. s. l.	Broken Arrow, Okla. (233 meters) Mean	Departure from normal	Due West, S. C. (217 meters) Mean	Departure from normal	Ellendale, N. Dak. (444 meters) Mean	Departure from normal	Groesbeck, Tex. (141 meters) Mean	Departure from normal	Royal Center, Ind. (225 meters) Mean	Departure from normal
Surface	3.8	+0.6	3.8	−1.6	−5.0	+6.1	6.5	−1.5	−0.8	+3.5
500	4.8	+2.0	5.0	−0.3	−4.8	+6.2	7.0	−0.5	−1.9	+3.5
1,000	4.0	+1.3	4.0	−0.5	−1.7	+7.1	5.7	−1.6	−2.9	+2.4
1,500	2.2	−0.2	2.7	−0.3	−3.3	+4.8	4.3	−2.1	−3.9	+1.9
2,000	0.6	−0.4	0.9	−0.2	−5.9	+3.7	1.9	−2.8	−5.2	+1.6
2,500	−1.7	−0.5	−1.4	−0.4	−8.4	+3.4	0.0	−2.6	−6.9	+1.8
3,000	−4.4	−0.7	−4.2	−1.0	−10.8	+3.6	−2.5	−2.8	−9.2	+1.8
4,000	−11.4	−2.2	−10.5	−2.1	−16.9	+2.9			−15.3	−0.2
5,000			−15.8	−1.8					−22.1	

RELATIVE HUMIDITY (%)

Altitude *Meters* m. s. l.	Broken Arrow Mean	Departure from normal	Due West Mean	Departure from normal	Ellendale Mean	Departure from normal	Groesbeck Mean	Departure from normal	Royal Center Mean	Departure from normal
Surface	75	+5	77	+7	80	−1	78	+1	80	+1
500	64	0	65	+3	78	−1	61	−9	79	+5
1,000	56	+1	58	+1	63	−3	52	−9	70	+7
1,500	51	+5	52	−1	60	+1	47	−6	61	+5
2,000	41	0	48	−1	60	+2	48	0	53	+2
2,500	37	−3	45	0	58	0	47	+2	49	−3
3,000	37	−3	44	+2	55	−3	43	+2	49	−4
4,000	34	−8	49	+8	55	+1			50	−4
5,000			75	+25					54	

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressure during January, 1931*—Continued

VAPOR PRESSURE (*mb.*)

Altitude *Meters* m. s. l.	Broken Arrow, Okla. (233 meters) Mean	Departure from normal	Due West, S. C. (217 meters) Mean	Departure from normal	Ellendale, N. Dak. (444 meters) Mean	Departure from normal	Groesbeck, Tex. (141 meters) Mean	Departure from normal	Royal Center, Ind. (225 meters) Mean	Departure from normal
Surface	6.08	+0.40	6.17	−0.55	3.51	+1.11	7.83	−1.03	4.75	+0.94
500	5.63	+0.57	5.61	−0.44	3.47	+1.12	6.46	−1.34	4.30	+0.99
1,000	4.64	+0.44	4.61	−0.67	3.36	+1.21	5.06	−1.44	3.38	+0.59
1,500	3.54	+0.17	3.73	−0.58	2.84	+0.87	3.94	−1.29	2.57	+0.24
2,000	2.45	−0.29	2.95	−0.52	2.33	+0.63	3.34	−0.84	2.02	+0.10
2,500	1.91	−0.39	2.39	−0.30	1.77	+0.38	2.83	−0.54	1.58	−0.07
3,000	1.52	−0.43	2.00	−0.11	1.26	+0.18	2.26	−0.40	1.23	−0.21
4,000	1.12	−0.29	1.42	+0.02	0.55	−0.03			0.89	−0.12
5,000			1.31	+0.18					0.67	

TABLE 2.—*Free-air data obtained at naval air stations during January, 1931*

Altitude (meters) m. s. l.	Temperature (° C.) Hampton Roads, Va.	Pensacola, Fla.	San Diego, Calif.	Washington, D. C.	Relative humidity (%) Hampton Roads, Va.	Pensacola, Fla.	San Diego, Calif.	Washington, D. C.
Surface	3.7	7.4	13.4	−1.4	73	80	60	73
500	3.5	7.7	13.5	−0.6	64	72	55	61
1,000	1.3	6.2	11.9	−1.6	58	64	45	56
2,000	−3.7	3.9	6.6	−5.3	52	51	40	49
3,000	−7.3	−1.0	0.6	−8.1	46	45	32	34

In Table 3 are shown the resultant free-air winds for a representative group of stations. The light resultant velocities and variable directions at the upper levels in the extreme western part of the country are conspicuous as compared with the more uniform northwesterly directions in the central and eastern sections.

TABLE 3.—*Free-air resultant winds (meters per second) based on pilot balloon observatoins made near 7 a. m. (E. S. T.) during January, 1931*

Altitude (meters) m. s. l.	Broken Arrow, Okla. (233 meters) Direction	Velocity	Brownsville, Tex. (12 meters) Direction	Velocity	Burlington, Vt. (132 meters) Direction	Velocity	Cheyenne, Wyo. (1,873 meters) Direction	Velocity	Due West, S. C. (217 meters) Direction	Velocity	Ellendale, N. Dak. (444 m.) Direction	Velocity
	°		°		°		°		°		°	
Surface	S 55 W	0.5	N 7 E	0.3	S 7 W	0.8	N 75 W	5.5	S 83 W	1.5	N 71 W	2.5
500	S 77 W	2.8	S	2.6	S 86 W	3.3			N 74 W	4.9	N 78 W	3.8
1,000	N 78 W	5.4	S 33 W	2.0	N 80 W	6.8			N 73 W	5.2	N 55 W	8.9
1,500	N 77 W	6.3	S 58 W	1.9	N 69 W	9.7			N 73 W	7.6	N 56 W	10.6
2,000	N 63 W	7.4	N 76 W	3.6	N 60 W	13.1	N 77 W	8.3	N 88 W	8.8	N 51 W	12.1
2,500	N 54 W	9.3	S 77 W	7.4	N 74 W	14.7	N 68 W	13.4	N 67 W	9.1	N 50 W	13.3
3,000	N 53 W	7.7	S 75 W	7.4			N 57 W	12.5	N 77 W	6.6	N 52 W	12.2
4,000			S 85 W	9.6			N 55 W	11.0				
5,000			S 78 W	11.1			N 71 W	7.6				

Altitude (meters) m. s. l.	Groesbeck, Tex. (139 meters) Direction	Velocity	Havre, Mont. (762 meters) Direction	Velocity	Jacksonville, Fla. (14 m.) Direction	Velocity	Key West, Fla. (11 meters) Direction	Velocity	Los Angeles, Calif. (127 meters) Direction	Velocity	Medford, Oreg. (410 meters) Direction	Velocity
	°		°		°		°		°		°	
Surface	N 50 W	0.7	S 62 W	3.7	N 50 W	1.4	N 39 E	2.9	N 35 E	2.2	S 17 W	0.5
500	N 78 W	2.4			N 44 W	2.6	N 61 E	5.4	N 57 E	1.3	S 27 E	1.3
1,000	N 71 W	4.6	S 71 W	9.1	S 88 W	3.5	N 65 E	3.2	N 74 E	0.9	S 30 E	3.8
1,500	N 65 W	4.4	N 85 W	10.7	N 83 W	5.8	S 28 W	0.4	N 85 E	1.6	S 7 W	4.0
2,000	N 57 W	4.1	N 75 W	12.4	N 62 W	6.4	S 55 W	1.7	N 81 E	2.5	S 36 W	5.2
2,500	N 74 W	5.9	N 69 W	10.1	N 66 W	8.7	N 89 W	3.7	N 66 E	2.2	S 47 W	5.6
3,000	N 80 W	6.2	N 68 W	11.2	N 72 W	10.8			S 68 W	1.2	S 84 W	2.8
4,000	S 80 W	5.5									S 50 W	1.7
5,000												

TABLE 3.—*Free-air resultant winds (meters per second) based on pilot balloon observations made near 7 a. m. (E. S. T.) during January, 1931*—Continued

Altitude (meters) m. s. l.	Memphis, Tenn. (145 meters)		Modena, Utah (1,665 meters)		New Orleans, La. (25 meters)		Omaha, Nebr. (299 meters)		Phoenix, Ariz. (356 meters)		Royal Center, Ind. (225 meters)		Salt Lake City, Utah (1,294 meters)		San Francisco, Calif. (8 meters)		Sault Ste. Marie, Mich. (198 meters)		Seattle, Wash. (14 meters)		Spokane, Wash. (606 meters)		Washington, D. C. (10 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°	
Surface	S 68 W	0.9	S 81 W	2.4	N 19 E	0.9	W	0.9	S 71 E	3.7	S 63 W	2.5	S 40 E	0.7	S 77 E	0.8	N 31 E	0.5	S 46 E	1.5	S 15 E	0.8	N 53 W	1.4
500	N 79 W	4.6	---	---	N 5 W	4.1	N 70 W	3.8	S 84 E	4.2	S 87 W	7.1	---	---	N 33 E	2.0	N 66 W	1.6	S 8 W	7.0	---	---	N 67 W	7.5
1,000	N 69 W	6.1	---	---	N 29 W	4.1	N 61 W	8.5	N 82 E	3.5	N 78 W	7.7	---	---	N 30 E	1.6	N 57 W	6.3	S 18 W	8.3	S 19 W	3.5	N 67 W	9.8
1,500	N 88 W	7.1	---	---	N 53 W	4.5	N 67 W	10.3	N 80 E	2.1	N 87 W	12.4	S 16 E	1.4	N 47 W	0.8	N 48 W	9.2	S 33 W	7.7	S 51 W	7.5	N 73 W	11.5
2,000	N 83 W	7.1	N 57 E	1.9	N 69 W	4.2	N 67 W	11.7	S 73 E	1.1	N 82 W	13.4	S 11 W	3.1	N 35 W	1.7	N 53 W	12.6	S 36 W	7.1	S 65 W	8.7	N 77 W	10.3
2,500	N 85 W	10.3	N 71 E	3.2	N 70 W	3.7	N 69 W	13.0	S 16 W	0.5	N 66 W	13.6	S 41 W	2.1	N 41 W	1.9	N 54 W	14.1	S 76 W	6.9	S 66 W	10.0	S 84 W	8.9
3,000	N 87 W	11.7	N 53 E	1.5	N 61 W	3.6	N 60 W	14.8	N 69 W	0.8	---	---	N 79 W	3.0	N 30 W	1.6	N 57 W	16.0	---	---	S 68 W	9.2	---	---
4,000	---	---	N 59 W	3.6	---	---	N 52 W	15.3	N 39 W	7.4	---	---	S 78 W	7.8	N 65 W	1.7	---	---	---	---	---	---	---	---
5,000	---	---	N 49 W	5.5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

TABLE 4.—*Observations by means of kites, captive and limited height sounding balloons during January, 1931*

	Broken Arrow, Okla.	Due West, S. C.	Ellendale, N. Dak.	Groesbeck, Tex.	Royal Center, Ind.
Mean altitudes, meters m. s. l., reached during month	2,823	2,640	2,997	2,561	2,895
Maximum altitude, meters m. s. l., reached	4,032	5,123	4,518	3,938	6,209
Number of flights made	31	33	29	21	28
Number of days on which flights were made	28	29	29	21	28

In addition to the above, there were approximately 176 scheduled pilot balloon observations made daily at 60 weather bureau stations in the United States.

WEATHER IN THE UNITED STATES

THE WEATHER ELEMENTS

By M. C. BENNETT

GENERAL SUMMARY

The month of January was abnormally warm and dry. However, in the extreme southern portions of the country, the more northeastern States, and the central Plateau the temperature averaged below normal. Elsewhere the month was generally warm, especially in the area between the Great Lakes and Rocky Mountains, where the monthly means were from 12° to 19° above the average.

The precipitation for the month was heavy in much of Texas, and normal or above in the Gulf section including Florida, and in the south Pacific districts and parts of Washington. Elsewhere the falls were generally scanty, with large areas continuing remarkably dry. In practically all central valley sections, and generally in the Great Plains, much of the Rocky Mountain region, and the central Plateau less than half the normal was received.

TEMPERATURE

The eastern and south-central portions of the country were experiencing moderately cool weather at the beginning of January, and in the coast districts from the Carolinas to the Rio Grande, likewise in the southern Appalachians and the lower Mississippi Valley, the low temperatures prevailed without material interruption until about the 22d. Conditions varied more in the Northeast and from the Ohio Valley northward, but the first three weeks were mainly milder than normal in these sections, expecially in the middle and western portions of the Lake region.

From the middle and upper Mississippi Valley westward over the Plains to the Rocky Mountains decidedly mild weather prevailed during the first three weeks, except for a brief cold period about the 12th to 14th. West of the divide there was usually warm weather in the Pacific States, but cold weather in a large part of the Plateau region.

The last 10 days of January were unseasonably warm in most districts, only a small area centering in northern Utah and a larger area covering nearly all of New York and New England, having colder weather than normal. Remarkably high temperatures for January were noted from the North Pacific States to Lake Superior and over the Plains and the central valleys. New high marks for January were noted at several stations during the last five days of the month.

The month resembled December just before it, being far warmer than normal in the north-central portion of the country and cooler than normal in the Southeast and in large portions of the Rio Grande Valley and the Plateau. Unlike December, January was warmer than normal in the Middle Atlantic States, the Ohio Valley, northern and central Texas, nearly all of Colorado, Nevada, and Idaho, and practically every part of the Pacific States. Only Utah and Florida sections averaged more than 2° colder than normal. Minnesota and the Dakotas averaged 13° to 15° warmer than normal, and over most North-central States this was the warmest January of record, or the warmest save 1880.

In California and Florida the highest temperatures came during the first week, but in almost every other State during the closing week. The lowest marks in the far West came during the opening decade, but from the Plains southeastward to the south Atlantic coast very near the middle of the month.

PRECIPITATION

The first eight days brought much precipitation in the Pacific States, and about the 11th there was considerable in Texas. The east Gulf and Atlantic regions received important amounts about the 5th, and substantially all their month's supply during the period from the 4th to the 18th. For almost all the country the last fortnight of January was without important precipitation.

The month was decidedly dry over the country as a whole. In this it resembled December just preceding, and, like December, there were moderate excesses in Florida and much of Texas. Unlike December, January brought more than normal precipitation to most of southern California and to Washington.

While the Gulf coast section had about as much rain as normal and the Lake region reported but a slight precipitation deficiency, yet most of the great area between the Rocky Mountain and Appalachian Divides had a marked deficiency, especially the middle and lower Ohio Valley, northern Arkansas, the Dakotas, and Minnesota. The middle and southern Plateau and the Middle Atlantic States likewise had considerable shortages.

As a result of the long-continued deficiency of precipitation, the major portions of the Mississippi and some other rivers were reported at the lowest stages ever known in midwinter.

Southwestern Texas, in marked contrast to a great part of the country, received more than three times the normal January rainfall, while in Florida, January, with about 120 per cent of normal, was the third successive month of more than normal rainfall.

SNOWFALL

There have been few Januarys with less snowfall, taking the country as a whole. The southern Middle Atlantic States, Ohio Valley, Minnesota and practically all the Plains had decidedly small amounts, compared with their average January quantities.

From eastern Iowa eastward and northeastward over the Lake region there was not so marked a deficiency; and New York, save the southeastern part, and almost all of New England had considerably more than normal snowfall. In New York no January since 1925 has brought so much snowfall as the present one, and the New England average amount for this month has been exceeded in January only three times within the last quarter century.

Most of the far West reported a considerable shortage of snowfall, compared with the expected quantity. The supply of stored snow in the higher portions is small, on the whole; it is usually least unsatisfactory near and for a moderate distance to westward of the Continental Divide, between the Canadian boundary and the central portions of Colorado and Utah.

The ground was bare to an extraordinary extent over the northern Plains and westward to the foothills of the Rockies, also in southern Minnesota and from Kansas and Missouri eastward over the Ohio Valley.

SUNSHINE AND RELATIVE HUMIDITY

Much cloudy weather prevailed in the region of the Great Lakes and upper Ohio Valley, southern Florida, the far Northwest and northern Pacific States, while in the western portion of the Great Plains much sunshiny weather prevailed, western North Dakota receiving about 70 per cent of the possible. Elsewhere about the normal amounts of sunshine were received. The relative humidity was generally above the normal in Texas and portions of the adjacent States, in much of the Great Basin and Plateau region, and portions of the Lake region and northern New England, while elsewhere it was generally near or below the normal. However, the departures from the normal were nowhere large.

SEVERE LOCAL STORMS, JANUARY, 1931

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the Annual Report of the Chief of Bureau]

Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Uniontown, Pa., and vicinity.	5	Noon	3,520		$100,000	Severe wind	Many buildings unroofed, some completely wrecked; overhead wires torn down; plate glass broken; many minor injuries.	Official, U. S. Weather Bureau.
Caswell County, N. C. (4 miles north of Yanceyville).	5	4 p. m.	200-300		10,000	Tornado	Number of buildings demolished, others unroofed; 2 persons injured; path 10 miles long.	Do. News and Observer (Raleigh N. C.).
Warren County, N. C. (3 miles west of Wise).	5	4.35 p. m.	100-200	6	35,000	Do	Farm buildings, a training school, and 2 churches demolished; poultry killed; trees uprooted or twisted off; path 4 miles long.	Official, U. S. Weather Bureau.
Mecklenburg County, Va. (near Boydton).	5	5 p. m.	100	1	3,500	Do	House and other buildings blown down; path 2 miles long.	Do. Washington Post (D. C.).

RIVERS AND FLOODS

By RICHMOND T. ZOCH

Floods in January, 1931, were local and of very minor importance. They occurred in the Santee, Savannah, and West Pearl Rivers, as shown in the following table.

An interesting occurrence in January, 1931, was the formation of an ice sheet at Saltair, near Salt Lake City, on Great Salt Lake. The sheet was observed on the morning of the 6th; it was about one-fourth inch thick, began at the shore, and extended out about 1,000 feet. This is the first known instance of the formation of ice on the open lake; a possible explanation of the cause of the freezing is given by Herman Harms, Utah State chemist, as follows:

> The prolonged cold spell has caused an unusually heavy precipitation of Glauber salts, one of the chief constituents next to sodium chloride. This has decreased the density of the water to such an extent as to permit freezing over the shallow water near the shore. The ordinary freezing point of Great Salt Lake water, which is nearly 23 per cent solid, would be from 20° to 25° below zero. With the density decreased by Glauber salts precipitation, however, the freezing point would be raised about 10°.

The freezing of Bear River Bay, a part of the lake, is said not to be unusual, but is due to an artificial condition. The embankment of the Lucin cut-off has almost completely separated Bear River Bay from the main body of the lake, and the water from Bear River freshens the bay water to an extent sufficient to allow freezing to take place. Also, considerable ice from Jordan River floats into the lake occasionally.

Table of flood stages in January, 1931

River and station	Flood stage	Above flood stages—dates: From—	Above flood stages—dates: To—	Crest: Stage	Crest: Date
ATLANTIC DRAINAGE					
Santee:	Feet			Feet	
Rimini, S. C.	12	20	22	12.2	22
Ferguson, S. C.	12	10	12	12.1	12
		14	25	12.7	18-19
Savannah: Ellenton, S. C.	13	8	11	14.3	9
		14	23	17.3	16
EAST GULF DRAINAGE					
West Pearl: Pearl River, La.	13	12	24	14.7	18

WEATHER OF THE ATLANTIC AND PACIFIC OCEANS

NORTH ATLANTIC OCEAN

By F. A. YOUNG

January is normally the stormiest month of the year over the North Atlantic. During the current month, however, the number of days with gales was considerably less than usual over the greater part of the ocean. The largest number of gales occurred over the region between the Bermudas and Maritime Provinces, where they were reported on from 2 to 5 days, while according to reports received, they did not occur on more than 4 days in any other 5° square.

As shown by Table 1, the average pressure at land stations in eastern Canada and Newfoundland was considerably below normal, while the North Atlantic HIGH was apparently well developed.

As in December, the number of days with fog was below the normal over practically the entire ocean. The maximum amount occurred in the square that includes the east coast of Newfoundland, where it was reported on seven days. Over the Grand Banks it was reported on from 4 to 5 days; over the steamer lanes, east of the fortieth meridian, on not more than one day in any 5° square; along the American coast, between the thirtieth and forty-fifth parallels, on from one to two days; in the Gulf of Mexico, on from one to two days.

Barometric data for several island and coast stations are given in the following table:

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, 8 a. m. (seventy-fifth meridian). North Atlantic Ocean, January, 1931*

Stations	Average pressure	Departure	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Julianehaab, Greenland	29.54	(1)	30.28	11th	28.74	26th.
Belle Isle, Newfoundland	29.80	−[2] 0.20	30.10	6th [3]	28.98	17th.
Halifax, Nova Scotia	29.82	−[4] 0.16	30.28	19th	28.92	7th.
Nantucket	29.96	−[4] 0.09	30.34	25th	29.22	31st.
Hatteras	30.08	−[4] 0.06	30.50	16th	29.22	6th.
Key West	30.10	−[4] 0.01	30.36	15th	29.84	5th.
New Orleans	30.19	+[4] 0.03	30.60	15th	29.68	5th.
Cape Gracias, Nicaragua	29.94	−[2] 0.04	29.98	2d [3]	29.90	5th.[3]
Turks Island	30.10	+[2] 0.05	30.22	16th	30.00	6th.
Bermuda	30.06	−[4] 0.10	30.28	18th [3]	29.76	7th.[3]
Horta, Azores	30.23	+[2] 0.13	30.66	15th [3]	29.44	2d.
Lerwick, Shetland Islands	29.62	−[2] 0.08	30.48	7th	28.66	23d.
Valencia, Ireland	29.97	+[2] 0.07	30.53	9th	29.35	31st.
London	29.91	−[2] 0.09	30.52	7th	29.20	1st.

[1] No normal available.
[2] From normals shown on Hydrographic Office Pilot Charts, based on observations at Greenwich mean noon, or 7 a. m., 75th meridian time.
[3] And on other date or dates.
[4] From normals based on 8 a. m. observations.

Charts VIII to XI cover the period from the 1st to 4th, inclusive, and Charts XII and XIII show the conditions on the 10th and 11th, respectively. These two latter charts were drawn to give an idea of the weather encountered by the ill-fated airplane *Tradewind* that took off from Bermuda for the Azores on the morning of the 10th and was lost at sea.

On the 5th moderate conditions prevailed over the greater part of the ocean, although the land stations at Tampico and Vera Cruz, Mexico, reported northerly winds, force 7 and 8, respectively, with a barometric reading of 30.14 inches at both stations. On this date there was a depression over the northern section of the Gulf of Mexico, with a barometric reading of 29.60 inches at Pensacola that afterwards developed into a severe disturbance as it moved northeastward along the coast.

On the 6th this LOW was central near New York, where the barometer read 28.96 inches; on the 7th it was over the Maritime Provinces, barometer at Halifax 28.92 inches; on the 8th central near Belle Isle, barometer 29.03 inches. This disturbance reached its greatest extent and intensity on the 7th, when the storm area extended from the thirtieth to forty-fifth parallels, west of the fiftieth meridian, and winds of force 10 to 12 were reported by vessels during this period from the 6th to 8th. During this same period there was also a LOW that remained nearly stationary in the vicinity of the Azores, accompanied by moderate to whole gales, and on the 8th the station at Horta reported, wind NE, 11, barometer 29.58 inches. By the 9th this LOW had apparently filled in, as there are no signs of it on the chart for that day.

On the 9th a depression was central about 300 miles northwest of Bermuda that moved northward, increasing in intensity, and on the 10th was central near Sydney, Nova Scotia. On the 10th and 11th the region between the thirty-fifth and forty-fifth parallels was swept by gales from nearly all points of the compass, reaching hurricane force at times.

From the 12th to 14th moderate conditions prevailed over the greater part of the ocean, although vessels in widely separated localities reported winds of force 7 and 8.

From the 15th to 17th there was another active disturbance between the Bermudas and fiftieth parallel that reached its greatest intensity on the 16th, when central near 42° N., 54° W. Reports from vessels involved are given in table of gales and storms. On the 17th southerly gales were also reported by vessels over the middle section of the steamer lanes, and northwesterly winds of force 7 and 8 by vessels in the vicinity of and at land stations on the British Isles.

On the 20th a LOW was off the west coast of Cuba, with winds of a maximum force of 10, as shown by report in table. This disturbance moved slowly northward, gradually filling in, and on the 21st moderate weather prevailed along the American coast, except that one vessel near Nassau encountered a northerly wind, force 7.

On the 21st a disturbance was central near 51° N., 38° W., that moved slowly eastward, and by the 24th and 25th was over the North Sea.

On the 26th and 27th gales also occurred between the thirtieth and fiftieth parallels and the thirtieth and forty-fifth meridians.

On the 28th and 29th a depression over the British Isles was responsible for moderate westerly and northwesterly gales over a limited area between the coast and twentieth meridian.

On the 30th Halifax was near the center of a LOW that on the 31st was central near Belle Isle, and on both dates westerly to northwesterly gales were encountered by vessels between the thirty-fifth and fiftieth parallels, west of the forty-fifth meridian. On the 31st moderate southwest gales were also reported by land stations on the south coast of England.

NOTE—American steamship *Carplaka*, Capt. A. J. Griggs; observer, A. Rasmussen. From New York to Copenhagen:

> On January 23, 1931, at 2.30 p. m., in latitude 57° 09′ N., longitude 23° 42′ W., observed a waterspout traveling from NW. to SE., overtaking vessel and crossing bow, vanishing in horizon in about 10 minutes. It appeared like dark smoke whirling apparently in a clockwise direction and extending about 100 feet above surface. Ship was steaming 74°, 13.5 knots an hour. This occurred during a hail squall of short duration, weather being clear with passing squalls. Barometer read 29.07 inches, air 39°, water 49°, wind WNW., 5, sea WNW, moderately rough.

OCEAN GALES AND STORMS, JANUARY, 1931

Vessel	Voyage: From—	Voyage: To—	Position at time of lowest barometer: Latitude	Position at time of lowest barometer: Longitude	Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Highest force of wind and direction	Shifts of wind near time of lowest barometer
NORTH ATLANTIC OCEAN			° ′	° ′				*Inches*					
Peter Kerr, Am. S. S.	London	Philadelphia	39 20 N	41 05 W	Dec. 30	4 a, 1	Jan. 3	29.08	WSW	W, 12	WNW	W, 12	Steady.
City of Alton, Am. S. S.	Antwerp	New York	44 25 N	40 20 W	Dec. 31	2 a, 1	Jan. 2	28.77	SSE	SW, 8	NNW	NNW, 12	SW-NW.
Motocarline, Belg. M. S.	Esbjerg	Baytown	41 59 N	27 52 W	Jan. 1	1 p, 1	do	29.33	SW	SW, 8	SW	SW, 10	Steady.
Coldwater, Am. S. S.	Antwerp	Charleston	32 48 N	65 58 W	do	2 a, 2	do	29.47	S	W, 10	N	—, 10	S-W-NW.
Collamer, Am. S. S.	Bordeaux	New York	35 20 N	58 00 W	Jan. 2	2 p, 2	do	29.37	S	SW, 10	NNW	SW, 10	SW-W-NW.
Emile Francqui, Fr. S. S.	Antwerp	do	45 05 N	45 30 W	Jan. 3	4 a, 3	Jan. 3	29.03	N	N, 12	N	N, 12	Steady.
McKeesport, Am. S. S.	Havre	do	47 48 N	28 00 W	do	2 a, 4	Jan. 4	29.12	SSE	S, 7	NW	NNW, 10	S-W-NNW.
Silverlarch, Br. M. S.	Genoa	do	36 23 N	68 13 W	Jan. 5	2 p, 6	Jan. 7	29.32	SSW	SW, 10	NW	SW, 10	SSW-WNW.
Peter Kerr, Am. S. S.	London	Philadelphia	36 20 N	59 50 W	Jan. 6	6 a, 7	Jan. 8	29.36	SW	WSW, 8	WNW	S, 12	SW-WSW.
Augustus, Ital. S. S.	Naples	New York	37 50 N	48 54 W	Jan. 7	4 p, 7	do	29.59	S	S, —	W	S, 11	S-W.
Peter Kerr, Am. S. S.	London	Philadelphia	37 05 N	64 05 W	Jan. 9	10 p, 9	Jan. 11	29.36	NNE	NNE, 10	NNW	NNE, 12	Steady.
Quaker City, Am. S. S.	Hull	do	42 31 N	61 20 W	Jan. 10	8 a, 10	do	29.53	ENE	ENE, 7	W	NW, 11	
Marie Leonhardt, Ger. S. S.	Antwerp	New York	36 01 N	73 22 W	Jan. 12	8 p, 12	Jan. 12	29.61	S	S, —	W	—, 11	
Bloomersdijk, Du. S. S.	Beaumont	Rotterdam	37 26 N	63 05 W	Jan. 15	3 p, 15	Jan. 16	28.80	WSW	WSW, 10	NW	NW, 12	WSW-WNW.
River Tigris, Br. S. S.	Gibraltar	New York	35 40 N	59 50 W	do	1 p, 15	do	29.51	W	W, —	NW	W, 12	W-NW.
Emile Francqui, Fr. S. S.	New York	Antwerp	41 42 N	55 00 W	do	4 a, 16	do	28.90	S	S, 11	SW	S, 11	S-SW.
Milwaukee, Ger. M. S.	Galway	New York	48 44 N	36 00 W	Jan. 17	10 a, 17	Jan. 18	29.55	SW	S, 11	WNW	S, 11	SW-S-WNW.
Amapala, Hond, S. S.	Canal Zone	New Orleans	25 10 N	87 20 W	Jan. 20	8 p, 20	Jan. 21	29.92	N	N, 9	N	N, 10	Steady.
Bellflower, Am. S. S.	New York	Glasgow	51 40 N	35 44 W	Jan. 21	5 p, 21	Jan. 22	29.32	NE	SSE, 7	W	W, 9	SSE-W.
Europa, Ger. S. S.	Cherbourg	New York	50 00 N	14 12 W	Jan. 23	11 a, 23	Jan. 23	29.32	SW	W, 10	W	W, 10	SW-WNW.
Bowes Castle, Br. S. S.	Galveston	Havre	38 48 N	62 24 W	Jan. 24	Mdt, 24	Jan. 25	29.93	NW	WNW, 10	N	—, 10	
Europa, Ger. S. S.	Cherbourg	New York	45 42 N	42 24 W	Jan. 25	1 a, 25	do	29.18	S	S, 9	NW	SW, 10	S-NW-WNW.
Rotterdam, Du. S. S.	Rotterdam	do	46 57 N	36 51 W	Jan. 26	9 a, 27	Jan. 28	29.64	SW	SW, 9	NW	SW, 9	
Bannack, Am. S. S.	Liverpool	Boston	51 20 N	24 30 W	Jan. 27	8 p, 29	Jan. 30	29.47	S	SSW, 8	NNW	—, 9	
Wytheville, Am. S. S.	New York	Rotterdam	50 51 N	32 00 W	Jan. 31	8 p, 31	Jan. 31	29.47	ESE	S, 9	SW	S, 9	ESE-SSW.
Express, Am. S. S.	Seville	New York	37 09 N	65 14 W	Jan. 30	Noon, 31	Feb. 1	29.47	NW	SW, 9	NW	SW, 10	
NORTH PACIFIC OCEAN													
President Grant, Am. S. S.	Yokohama	Seattle	50 13 N	173 41 W	Jan. 1	4 p, 5	Jan. 7	27.78	NNW	S, 8	SSW	ESE, 10	E-SE-SW.
Diana Dollar, Am. S. S.	Tobaco, P. I.	Los Angeles	38 24 N	171 23 E	do	11 p, 1	Jan. 2	29.63	W	W, 9	WNW	W, 10	1 point.
Arabia Maru, Jap. S. S.	Yokohama	Vancouver	49 43 N	134 10 W	Jan. 2	3 a, 3	Jan. 3	29.03	SE	SE, 8	SSE	WSW, 9	W-S-SSE.
Diana Dollar, Am. S. S.	Tabaco, P. I.	Los Angeles	41 09 N	174 40 W	Jan. 3	3 a, 4	Jan. 4	29.29	SSE	SSE, 10	W	W, 10	10 points.
Edgemoor, Am. S. S.	San Pedro	Yokohama	33 35 N	160 00 E	do	2 a, 4	do	29.48	SW	WNW, —	NW	NW, 9	WSW-NW.
Silverelm, Br. M. S.	Manila	San Francisco	39 21 N	170 07 E	do	6 a, 4		28.90	SE	SW, 12		—, 12	SW-W-WNW.
Bellingham, Am. S. S.	Hong Kong	do	44 40 N	168 30 E	do	7 a, 4	Jan. 6	28.66	E	NNE, 10	SW	W, 10	4 points.
Scalaria, Br. S. S.	Kobe	San Pedro	47 06 N	175 15 W	do	Noon, 4	Jan. 8	28.06	SE	SW, 10	SW	SW, 12	WSW-S-SW.
Northwestern, Am. S. S.	Seattle	Seward	58 14 N	137 16 W	Jan. 4	2 a, 4	Jan. 4	28.92	NE	NE, 7	N	NE, 9	NE-N.
Golden Peak, Am. S. S.	Shanghai	San Francisco	40 25 N	164 55 W	do	11 a, 4	Jan. 5	29.29	SE	S, 9	W	S, 9	SE-S-W.
Emma Alexander, Am. S. S.	San Diego	Seattle	45 00 N	124 50 W	Jan. 5	6 a, 5	do	29.21	SE	Calm	NW	NW, 12	SE-NW.
Empress of Canada, Br. S. S.	Yokohama	Vancouver	49 23 N	167 15 W	do	1 p, 6	Jan. 7	28.19	SW	SW, 11	SSW	SW, 11	SSE-S-SW.
San Pedro Maru, Jap. M. S.	Takao	San Francisco	36 08 N	152 03 E	Jan. 6	6 p, 10	Jan. 12	29.18	NE	SW, 6	NW	S, 10	NE-E-S.
Arizona Maru, Jap. S. S.	Yokohama	Victoria	50 12 N	156 35 W	Jan. 9	8 p, 9	Jan. 10	28.83	SE	SSW, 9	SSW	SSW, 9	SE-SW-SSW.
Kentucky, Am. S. S.	Hong Kong	San Francisco	28 29 N	129 18 E	do	4 p, 9	do	29.84	NW	NW, 4	NW	NW, 9	Steady.
Scalaria, Br. S. S.	Kobe	San Pedro	43 50 N	145 40 W	Jan. 10	10 p, 10	Jan. 11	29.30	SE	S, 7	WNW	W, 9	SE-S-WNW.
Choyo Maru, Jap. S. S.	Miike	Seattle	46 38 N	176 36 E	Jan. 11	Mdt, 11	do	29.07	S	SW, 3	SW	SE, 10	8 points.
Nora, Am. S. S.	San Pedro	Yokohama	30 41 N	156 35 E	Jan. 14	Noon, 14	Jan. 14	29.83	SW	SW, 9	W	W, 10	SW-W.
Golden Star, Am. S. S.	Hong Kong	San Francisco	40 28 N	154 51 W	do	2 p, 15	Jan. 15	29.28	S	S, 5	NW	S, 11	S-W-NW.
Choyo Maru, Jap. S. S.	Miike	Seattle	49 08 N	158 07 W	do	4 p, 15	Jan. 17	28.43	S	S, 4	SE	SE, 11	4 points.
San Pedro Maru, Jap. M. S.	Takao	San Francisco	38 34 N	178 50 E	do	4 p, 15	Jan. 15	29.02	SE	WSW, 8	NW	W, 11	SE-SW-NW.
Holystone, Br. S. S.	Panama	Vancouver	43 22 N	125 00 W	Jan. 15	3 p, 15	Jan. 16	29.80	S	SW, 7	NW	W, 10	S-SW-W.
City of Victoria, Can. S. S.	Japan	Port Alice	50 37 N	161 58 W	do	6 p, 15	Jan. 17	28.19	ESE	SE, 7	ESE	ESE, 9	SE-ESE.
Shabonee, Br. S. S.	Manila	San Pedro	35 52 N	166 14 W	do	9 p, 15	do	29.14	S	—, 10	NW	—, 10	S-SW-W.
Golden Star, Am. S. S.	Hong Kong	San Francisco	40 45 N	148 37 W	Jan. 16	5 a, 16	do	29.58	SW	SE, 8	W	SE, 9	S-SW-W.
Shabonee, Br. S. S.	Manila	San Pedro	35 52 N	149 30 W	Jan. 18	—, 19	Jan. 19	29.14	S	—, —	NW	—, 11	SSW-W-WNW.
Hanover, Am. S. S.	do	do	39 55 N	166 00 W	Jan. 21	5 a, 22	Jan. 22	29.12	S	S, 8	S	S, 9	Steady.
Admiral Watson, Am. S. S.	San Francisco	Portland, Oreg	43 49 N	124 23 W	do	10 p, 21	Jan. 23	29.60	SE	—, 8	S	—, 9	SE-S.
San Diego Maru, Jap. M. S.	Elwood	Kudamatsu	32 35 N	138 45 E	Jan. 22	3 p, 23	do	29.71	S	WSW, 8	NW	SW, 9	WSW-NW.
Modjokerto, Du. S. S.	Menato	Los Angeles	33 30 N	141 30 W	Jan. 23	Noon, 24	Jan. 24	29.68	S	SW, 9	SW	SW, 9	S-SW-WSW.
Nora, Am. S. S.	Yokohama	San Pedro	35 02 N	148 00 E	do	8 a, 23	Jan. 25	29.72	S	S, 7	NW	W, 9	W-NW.
Hakubasan Maru, Jap. M. S.	do	San Francisco	46 25 N	174 00 W	Jan. 24	3 p, 27	Jan. 28	28.43	ESE	SSE, 8	SSW	SSW, 9	ESE-S-WSW.
Paul Luckenbach, Am. S. S.	New York	San Pedro	15 25 N	94 35 W	do	4 p, 24	Jan. 25	29.81	NW	N, 9	NW	—, 9	NW-N-NNE.
William Penn, Am. M. S.	Iloilo, P. I.	do	30 22 N	166 32 E	do	6 p, 25	Jan. 26	29.69	WSW	WNW, 7	WNW	—, 9	WNW-WSW.
Emidio, Am. S. S.	Richmond Beach, Wash.	do	44 55 N	124 30 W	Jan. 25	6 a, 25	Jan. 25	29.77	S	S, 9	SSW	SSW, 9	S-SSW.
Hiye Maru, Jap. M. S.	Yokohama	Victoria	45 27 N	163 09 E	Jan. 26	1 a, 28	Jan. 28	28.02	ESE	S, 6	S	WSW, 10	SE-SW.
Makua, Am. S. S.	Columbia River.	Honolulu	36 00 N	141 15 W	Jan. 27	8 p, 27	do	29.50	SE	SE, 10	SW	—, 10	SE-SW.
Ixion, Br. S. S.	Yokohama	Victoria	49 20 N	178 12 W	do	7 p, 27	Jan. 29	27.99	E	E, 6	S	ENE, 10	SE-E-S.
Wisconsin, Am. S. S.	Japan	San Francisco	47 35 N	179 30 W	do	7 a, 29	do	28.02	SE	W, 4	W	W, 9	SE-NW-NE.
Ohioau, Am. S. S.	Los Angeles	New York	Morro Ayuca, L. H.		Jan. 29	4 p, 29	do	29.88	NNE	NNE, 8	N	NNE, 9	NNE-N.
Northwestern, Am. S. S.	Seattle	Seward	60 35 N	146 00 W	do	2p, 29	do	29.08	E	E, 7	NE	E, 9	E-NE.

NORTH PACIFIC OCEAN

By WILLIS E. HURD

Atmospheric pressure.—During December, 1930, pressure showed a great tendency to fall in the Aleutian region. The descent continued in January, and for this month unprecedentedly low averages occurred over the Alaskan Peninsula and neighboring islands. At Dutch Harbor, with a maximum daily barometric reading of 29.68 inches and a minimum of 28.22, the average for the first time on record for any month was below 29 inches and more than six-tenths of an inch below the normal. Between Dutch Harbor, with 28.94 inches, and Honolulu, where the average was 30.07, there existed a mean gradient for the month of 1.13 inches. The LOW extended well into the central Pacific, and as a consequence the usual anticyclone of middle latitudes was generally unstable and much restricted in area. On the average

it covered the coastal waters of the United States from Oregon to Lower California and the major part of the ocean otherwise between the fifteenth and thirtieth parallels.

The following table gives barometric data for several island and coast stations in west longitudes, including Point Barrow on the Arctic Ocean:

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level at indicated hours, North Pacific Ocean and adjacent waters, January, 1931*

Stations	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Point Barrow [1]	30.06	−0.02	30.72	21st	29.60	8th.
Dutch Harbor [1]	28.94	−0.64	29.68	4th	28.22	6th.
St. Paul [1]	29.07	−0.56	29.76	4th	28.44	7th.
Kodiak [1]	29.11	−0.48	29.60	17th	28.66	14th.
Midway Island [1]	29.99	−0.04	30.26	10th [3]	29.64	25th.
Honolulu [2]	30.07	+0.07	30.26	1st	29.88	26th.
Juneau [2]	29.62	−0.26	30.26	17th	28.97	4th.
Tatoosh Island [2] [4]	29.94	0.00	30.48	17th	29.33	22d.
San Francisco [2] [4]	30.12	+0.03	30.32	16th	29.75	7th.
San Diego [2] [4]	30.07	+0.01	30.32	4th	29.80	6th.

[1] Averages from p. m. observations only.
[2] A. m. and p. m. observations.
[3] And on the 11th.
[4] Corrected to 24-hour mean.

NOTE.—Beginning with January, 1931, new normals of atmospheric pressure are in use for Midway Island and the Alaskan substations appearing in this table. For Dutch Harbor, St. Paul, Kodiak, and Midway Island the average covers a period of 12 years and for Point Barrow 8 years. Data are compiled to include the year 1928.

January, 1931, was peculiarly a stormy month on the North Pacific Ocean and no day passed without gales in some portion of the sea, although they were generally well distributed over all the region from the thirtieth parallel northward. According to reports already received wind forces of 11 to 12 occurred on at least 10 days of the month, and forces of 10—whole gales—on more than half the days, in many cases blowing simultaneously in connection with widely separated disturbances. The tabular statement—Ocean gales and storms—presents a picture of the general storminess, showing gales of force 9 and upward, which needs no fuller amplification in text.

Several of the important local gales of major storm force were associated with the activities of the Aleutian LOW; some were due to the sharp expansion of the cyclone region against the immediately outlying anticyclone, which resulted in the formation of sudden steep barometric gradients, while others accompanied the more powerful of the progressive cyclones.

The severest cyclone of the month originated south of Japan on the 1st or 2d and began moving rapidly northeastward. By the 3d, then central at some distance southeast of the Kuril Islands, it attained hurricane intensity. On the 4th, south of the central Aleutians, it was causing dangerous gales over a great region along the upper routes between 160° E. and 170° W. On the 5th and 6th, now of great depth and continuing high wind intensity, it crossed the eastern Aleutians. The following three days witnessed its rapid decadence as it contracted in area and wandered aimlessly over the eastern waters of the Bering Sea. This storm was remarkable for its extremely low central pressure during the 4th and 5th, corrected barometer readings from the American steamer *President Grant* running below 28 inches for several hours, the minimum being 27.78, in 50° 13′ N., 173° 41′ W., on the 5th.

On the 5th, also, on the eastern extremity of the general Aleutian disturbance, hurricane velocities from the northwest occurred off the Washington coast near North Head, and strong to storm gales, mostly southerly, were encountered off this and the Oregon coast on the 21st, 22d, and 25th. A maximum velocity of 67 miles an hour from the south was recorded on the 22d at the Weather Bureau station on Tatoosh Island.

Midway along the sailing routes between the United States and Honolulu gales of force 8 to 10 occurred on 8 or more days, this region being unusually stormy. The period of most prolonged storminess here was from the 23d to 27th.

As indicative of the unusually long-sustained southward extension of the storm area for January this year, it is necessary only to remark that gales of force 8 to 10 occurred at various times and in various longitudes on about half the days of the month even in as low a latitude as that of the thirtieth parallel, a fact that, in the opinion of the writer, can not be duplicated by any other month of record.

In the China Sea one typhoon—the only North Pacific tropical cyclone of the month—was a brief disturbing weather factor. This is treated in the subjoined article. The northeast monsoon, however, blew at times with fresh gale force on several days, particularly on the 10th to 16th west of the Philippine Islands.

In and near the Gulf of Tehuantepec northers of gale force—8 to 10—were unusually frequent, occurring on at least 12 days of the month.

Strong northeast trades, rising to moderate gale force, were reported by the American steamer *Sierra* between 1° and 15° north latitude south of the Hawaiian Islands on the 13th to 15th.

At Honolulu the wind was generally light with prevalence from the east. The maximum velocity was 24 miles an hour from the northeast on the 18th.

Fog was rarely encountered on the Pacific this month except along or at no great distance from the coasts. Vessels up to time of this writing (March 2) have reported fog off the China coast on 6 days and in American waters between Vancouver and San Diego on 11 days.

TYPHOONS AND DEPRESSIONS

FIRST DESTRUCTIVE TYPHOON OVER THE PHILIPPINES IN 1931, JANUARY 3 AND 4

By REV. JOSÉ CORONAS, S. J.

[Weather Bureau, Manila, P. I.]

The Philippines have been visited at the beginning of this year by a very destructive typhoon, more severe than any of the typhoons experienced in our archipelago during the past year, 1930. Taking into consideration the Provinces most affected by this typhoon, it can be compared with that of October 15, 1912, although it was not so deep and of much less extension. Yet great damage was done to the crops and to the public and private properties, thousands of people remained homeless, besides a considerable loss of life that has been reported from several Provinces.

The typhoon was probably formed on December 30, 1930, nearly 300 miles to the south of Guam in about 145° longitude E. and 9° latitude N. It moved W. by N. and passed near to the north of Yap at 11 p. m. of December 31 when a barometric minimum of 749 mm. (29.49 ins.) was recorded with winds from W., force 5. From 2 to 10 p. m. of January 2 the typhoon took a WSW. direction: hence instead of entering the Philippines through the southern part of Samar, as it could be anticipated, it

came to pass through the Surigao Strait between Surigao and the southern coast of Samar. After 10 p. m. of the 2d the typhoon moved again to WNW. and W. by N. toward the central part of Leyte and the northern part of Cebu and Panay Islands. From Panay the typhoon moved northwest toward the southern coast of Mindoro and then into the China Sea, when it gradually filled up on the 5th or 6th in the neighborhood of the Paracels.

The barometric minimum reported from our stations was that of Dumalag, Capiz, 737 mm. (29.02 ins.) with winds veering from NW. to N., NE., E., and S. Relative calm was observed at Tuburan, Cebu, between 8.30 and 8.40 a. m. of the 3d.

The rate of progress of this typhoon was far from being uniform; because while from 2 to 6 a. m. of the 3d it moved at the heavy rate of about 20 miles per hour, from 6 a. m. to 2 p. m. of the same day the rate was slightly over 11 miles per hour.

The approximate positions of the center of this typhoon from December 31 to January 5 were as follows:

December 31, 6 a. m., 142° 20′ longitude E., 9° 20′ latitude N.
December 31, 11 p. m., 138° 15′ longitude E., 9° 50′ latitude N.
January 1, 6 a. m., 135° 45′ longitude E., 10° 10′ latitude N.
January 2, 6 a. m., 130° 45′ longitude E., 10° 40′ latitude N.
January 2, 10 p. m., 126° 25′ longitude E., 10° 10′ latitude N.
January 3, 2 a. m., 125° 40′ longitude E., 10° 25′ latitude N.
January 3, 6 a. m., 124° 20′ longitude E., 10° 50′ latitude N.
January 3, 2 p. m., 122° 50′ longitude E., 11° 10′ latitude N.
January 4, 6 a. m., 120° 40′ longitude E., 12° 25′ latitude N.
January 5, 6 a. m., 116° 50′ longitude E., 15° 30′ latitude N.

BUCKET OBSERVATIONS OF SEA-SURFACE TEMPERATURES

By GILES SLOCUM

STRAITS OF FLORIDA AND CARIBBEAN SEA

With the January, 1931, issue of the MONTHLY WEATHER REVIEW is initiated the monthly publication of a summary of Greenwich mean noon "Bucket observations" of temperatures at the surface of the water for the month one year preceding the date borne by the issue, in the Straits of Florida and the Caribbean Sea.

The "Caribbean Sea" is here defined as the area included between the American Continents on the south and west and the Greater Antilles and outermost Lesser Antilles on the north and east. The entire Mona Passage, the Windward Channel south of 20° N., and the Yucatan Channel north to 22° N., west on this parallel to 87° W., and south to the Yucatan Peninsula, are included, but observations from Lake Maracaibo are omitted.

The "Straits of Florida" data refer to the area bounded on the east by the eightieth meridian, on the north by the twenty-fifth parallel, on the west by the eighty-fourth meridian, and on the south by the Cuban coast.

As is well known, the method of taking bucket observations consists of drawing up with a canvas bucket thrown over the side of the ship a sample of the water near the surface. The temperature of this sample is immediately taken with a mercurial thermometer and recorded on the proper form. In a small but unknown number of cases other methods, such as measurement of the temperature at the condenser intake, are used by the mariners.

The variation of weather conditions from day to day have modifying effects on the temperatures of the water surface and, while the number of measurements of these temperatures within a stated area in any one day is, to a considerable degree, due to elements of chance, and subject to wide fluctuations. The truest mean temperature, then, will not result from weighting equally either the individual observations or those collectively of the single days, and a longer unit-period of time is needed.

The month, therefore, has been divided into four nearly equal "Quarters," each quarter embracing a period of either seven or eight days, as shown in Table 1. The mean of the averages of the four quarters is adopted as the mean temperature for the area during the month.

This gives a uniform method of computing the means for months of unequal length. The quarter-month is a period short enough to practically exclude, in tropical and subtropical latitudes, any seasonal march between its beginning and its end, but is yet long enough to smooth out daily chance fluctuations in the number of observations taken, and to make their number within each period of the same order of magnitude, justifying the assigning of roughly equal weights to them.

In computing the means for each 5-degree square in the Caribbean, however, the use of this refinement is not possible, and the means used are the sums of the temperatures for the months divided by the numbers of observations.

From this, it is obvious than an even greater number of observations than is available would be highly desirable, and, lacking this greater number, it is important that no genuinely pertinent information be neglected to round out the data, but such observations as are taken in port are not used because of various factors affecting their direct comparability with those taken on the open seas.

On this basis, and subject to these limitations, Table 2 shows the mean temperature for the Caribbean Sea and the Straits of Florida for January of each year from 1919 to 1930, inclusive, and Table 3 summarizes the temperature for the month in the same area, including the departures of the January, 1930, means from the 11-year means for January (1920–1930), and the changes from the temperatures for the preceding month of December, 1929.

The means for 1919, it will be noted, are not used in the computations or comparisons, the poor distribution and dearth of data for that year making them somewhat unreliable.

The chart at the end of this article shows the number of observations taken during the month of January, 1930, within each 1° square; the mean temperatures of the Straits of Florida and of each 5° [1] square in the Caribbean Sea; the 11-year means (1920–1930), for these areas; and the local mean time corresponding to Greenwich mean noon, at which time the mariners are instructed to make the temperature readings.

TABLE 1.—*Lengths of "Quarter months" used in computing mean sea-surface temperatures*

Length of month	Days of month included in quarter			
	I	II	III	IV
28 days	1–7	8–14	15–21	22–28
29 days	1–7	8–14	15–21	22–29
30 days	1–7	8–15	16–22	23–30
31 days	1–7	8–15	16–23	24–31

[1] In three cases, indicated on the chart, tha observations from small, little traveled, and unimportant areas have been treated as parts of the contiguous 5° squares.

TABLE 2.—*Mean surface temperatures in the Caribbean Sea and the Straits of Florida for January, 1930*

Year	Caribbean Sea		Straits of Florida	
	Number of observations	Mean temperature	Number of observations	Mean temperature
1919 [1]	14	78.7	11	75.4
1920	113	79.2	22	73.6
1921	192	78.8	58	75.2
1922	216	79.0	79	74.9
1923	270	78.0	74	75.1
1924	353	78.7	87	75.8
1925	272	79.0	123	75.8
1926	314	79.7	133	74.5
1927	318	79.3	150	74.6
1928	403	79.0	134	73.7
1929	519	79.2	136	75.2
1930	538	78.7	153	75.6
Mean (1920–1930)		79.0		74.9

[1] Not used in computations because of insufficient data available.

TABLE 3.—*Mean sea-surface temperatures (°F.), and number of observations, January, 1930*

Quarter	Period	Caribbean Sea				Straits of Florida			
		Number of observations	Mean (° F.)	Departure from 11-year mean (1920–1930) (° F.)	Change from preceding month (° F.)	Number of observations	Mean (° F.)	Departure from 11-year mean (1920–1930) (° F.)	Change from preceding month (° F.)
I	Jan. 1–7	124	79.0			43	75.3		
II	Jan. 8–15	131	78.8			42	75.8		
III	Jan. 16–23	135	78.8			34	76.3		
IV	Jan. 24–31	148	78.2			34	74.9		
Month		538	78.7	−0.3	−1.4	153	75.6	+0.7	−1.1

CLIMATOLOGICAL TABLES

DESCRIPTION OF TABLES AND CHARTS

Table 1 gives the data ordinarily needed for climatological studies for about 184 Weather Bureau stations making simultaneous observations at 8 a. m. and 8 p. m. daily, seventy-fifth meridian time, and for about 32 others making only one observation. The altitudes of the instruments above ground are also given.

Beginning January 1, 1928, movement and velocity of the wind are printed as recorded by the 3-cup anemometer, which has replaced the 4-cup pattern.

Table 2 gives, for about 37 stations of the Canadian Meteorological Service, the means of pressure and temperature, total precipitation, depth of snowfall, and the respective departures from normal values except in the case of snowfall. The sea-level pressures have been computed according to the method described by Prof. F. H. Bigelow in the REVIEW of January, 1902, **30:** 13–16.

CHART I.—*Temperature departures.*—This chart presents the departures of the monthly mean surface temperatures from the monthly normals. The shaded portions of the chart indicate areas of positive departures and unshaded portions indicate areas of negative departures. Generalized lines connect places having approximately equal departures of like sign. This chart of monthly surface temperature departures in the United States was first published in the MONTHLY WEATHER REVIEW for July, 1909, but smaller charts appear in W. B. Bulletin U for 1873 to June, 1909, inclusive.

CHART II.—*Tracks of centers* of ANTICYCLONES; and CHART III.—*Tracks of centers* of CYCLONES. The Roman numerals show the chronological order of the centers. The figures within the circles show the days of the month, the location indicated being that at 8 a. m., seventy-fifth meridian time. Within each circle is also an entry of the last three figures of (Chart II) the highest barometric reading, or (Chart III) the lowest reading reported at or near the center at that time, in both cases as reduced to sea level and standard gravity. The intermediate 8 p. m. locations are indicated by dots. The inset map of Chart II shows the departure of monthly mean pressure from normal and the inset of Chart III shows the change in mean pressure from the preceding month.

The use of a new base map for Charts II and III began with the January, 1930, issue.

CHART IV.—*Percentage of clear sky between sunrise and sunset.*—The average cloudiness at each regular Weather Bureau station is determined by numerous personal observations between sunrise and sunset. The difference between the observed cloudiness and 100 is assumed to represent the percentage of clear sky, and the values thus obtained are the basis of this chart. The chart does not relate to the nighttime.

CHART V.—*Total precipitation.*—The scales of shading with appropriate lines show the distribution of the monthly precipitation according to reports from both regular and cooperative observers. The inset on this chart shows the departure of the monthly totals from the corresponding normals, as indicated by the reports from the regular stations.

CHART VI.—*Isobars at sea level, average surface temperatures, and prevailing wind directions.*—The pressures have been reduced to sea level and standard gravity by the method described by Prof. Frank H. Bigelow in the REVIEW for January, 1902, **30:** 13–16. The pressures have also been reduced to the mean of the 24 hours by the application of a suitable correction to the mean of 8 a. m. and 8 p. m. readings at stations taking two observations daily, and to the 8 a. m. or the 8 p. m. observation, respectively, at stations taking but a single observation.

The diurnal corrections so applied, except for stations established since 1901, will be found in the Annual Report of the Chief of the Weather Bureau, 1900–1901, volume 2, Table 27, pages 140–164.

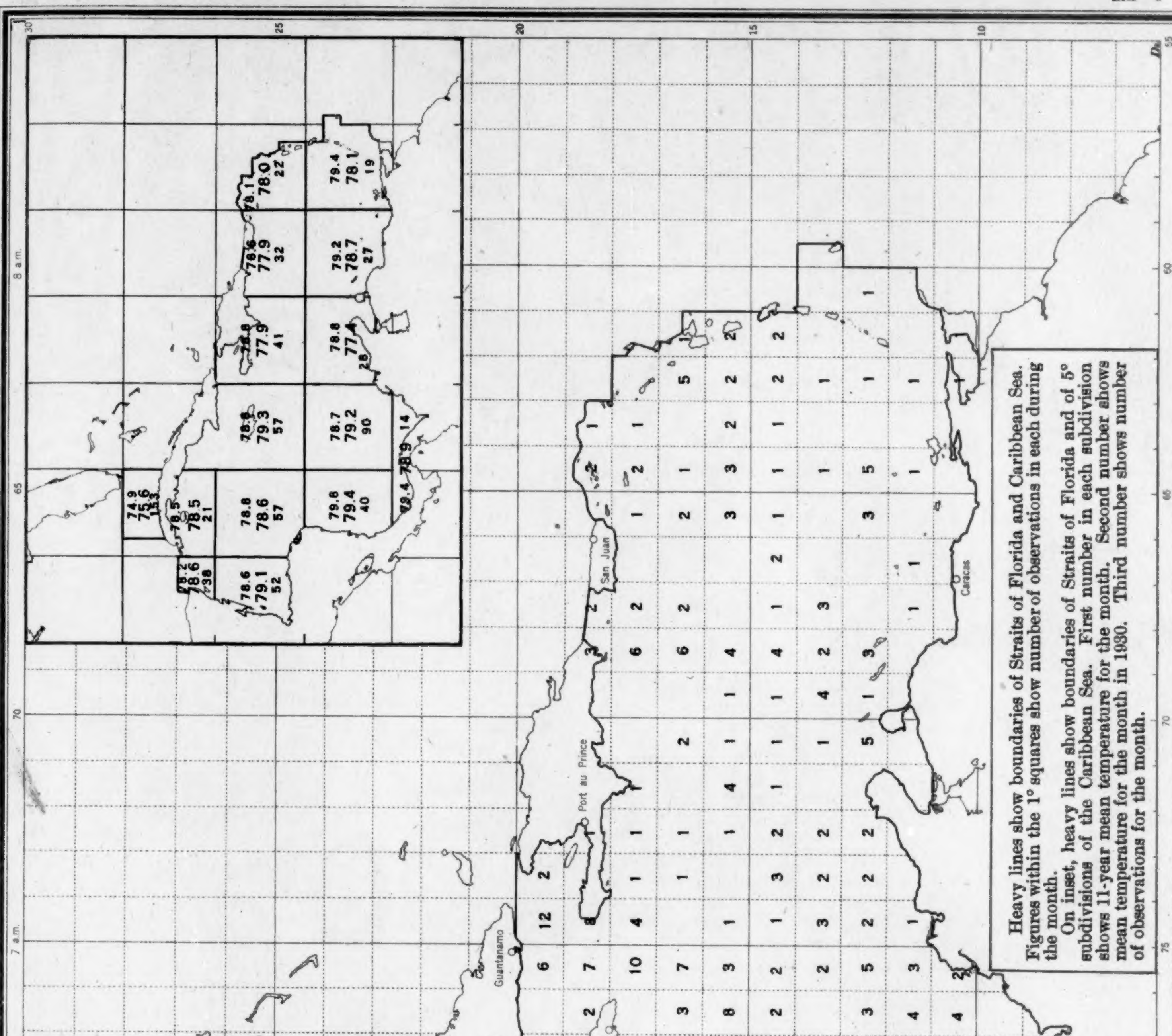
The sea-level temperatures are now omitted and average surface temperatures substituted. The isotherms can not be drawn in such detail as might be desired, for data from only the regular Weather Bureau stations are used.

The prevailing wind directions are determined from hourly observations at almost all the stations. A few stations determine their prevailing directions from the daily or twice-daily observations only.

CHART VII.—*Total snowfall.*—This is based on the reports from regular and cooperative observers and shows the depth in inches of the snowfall during the month. In general, the depth is shown by lines connecting places of equal snowfall, but in special cases figures also are given. This chart is published only when the snowfall is sufficiently extensive to justify its preparation. The inset of this chart, when included, shows the depth of snow on the ground at the end of the month.

CHARTS VIII, IX, etc.—*North Atlantic Weather maps of particular days.*

Distribution of Greenwich Mean Noon Bucket Observations of Sea-Surface Temperatures, January, 1930



Distribution of Greenwich Mean Noon Bucket Observations of Sea-Surface Temperatures, January, 1930
(Plotted by Giles Slocum)

CLIMATOLOGICAL TABLES[1]

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, January, 1931

Section	Temperature								Precipitation					
	Section average	Departure from the normal	Monthly extremes						Section average	Departure from the normal	Greatest monthly		Least monthly	
			Station	Highest	Date	Station	Lowest	Date			Station	Amount	Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	45.0	−1.0	Brewton (near)	78	28	Riverton	11	15	3.10	−1.88	Mobile	5.43	Madison	1.80
Arizona	42.8	−0.3	3 stations	84	[1] 22	Ganado	−8	5	0.47	−0.72	Oracle	1.70	10 stations	0.00
Arkansas	42.3	+1.3	4 stations	76	[1] 25	Corning	0	15	1.14	−3.10	El Dorado	3.40	Harrison	T.
California	45.4	+1.2	King City	89	4	Twin Lakes	−6	8	4.14	−1.32	Kennett	13.92	2 stations	T.
Colorado	25.0	+1.6	2 stations	70	29	Sunbeam	−28	16	0.17	−0.72	Savage Basin	2.00	27 stations	0.00
Florida	56.4	−2.5	5 stations	83	[1] 5	Mount Pleasant	20	15	3.38	+0.56	Miami	7.07	Hypoluxo	1.15
Georgia	46.1	−0.6	Quitman	78	[1] 25	Clayton	11	2	2.91	−1.30	Americus	4.15	Meldrim	1.50
Idaho	24.1	+1.6	Lapwai	58	28	3 stations	−22	[1] 1	1.41	−0.74	Roland	5.67	Twin Falls Factory	0.05
Illinois	33.2	+6.5	Carbondale	74	30	Freeport	−11	21	0.57	−1.75	Grand Chain	1.33	Griggsville	0.11
Indiana	33.2	+4.8	2 stations	69	[1] 24	Valparaiso	−11	15	0.80	−2.33	Valparaiso	2.68	Whiting	0.22
Iowa	28.9	+10.4	do	64	[1] 24	Decorah	−15	21	0.50	−0.57	Waverly	0.97	Lake Park (near)	T.
Kansas	36.4	+7.0	Ashland	75	24	2 stations	−4	14	0.26	−0.36	Le Roy	1.57	13 stations	0.00
Kentucky	37.7	+2.3	2 stations	72	[1] 26	Lovelaceville	−9	15	1.23	−3.12	Bowling Green (No. 2).	3.21	Anchorage	0.37
Louisiana	49.7	−1.6	3 stations	77	28	3 stations	21	15	5.83	+1.13	Grand Coteau	11.28	Tallulah	2.74
Maryland-Delaware	34.6	+1.7	do	66	[1] 25	Oakland, Md	−8	22	1.72	−1.50	Darlington, Md	2.35	Picardy, Md	0.71
Michigan	25.2	+5.2	2 stations	52	25	Wolverine	−20	7	1.26	−0.62	Ada	2.75	Traverse City	0.51
Minnesota	20.8	+13.0	Canby	60	29	Big Falls	−31	14	0.17	−0.58	Pigeon River Bridge	1.52	13 stations	T.
Mississippi	45.8	−1.2	Brookhaven	79	27	Holly Springs	13	15	3.54	−1.44	Magnolia	7.82	Hernando	1.13
Missouri	36.0	+5.5	2 stations	76	[1] 29	Goodland	−5	15	0.69	−1.35	Marble Hill	2.12	Fulton	0.07
Montana	28.6	+10.3	4 stations	69	29	Frazer	−26	13	0.35	−0.57	Heron	5.25	Savage	0.00
Nebraska	32.2	+10.7	Franklin	73	29	Gordon	−12	14	0.22	−0.33	Newport	1.00	12 stations	0.00
Nevada	31.6	+1.5	Logandale	84	28	Beowawe	−14	4	0.47	−0.65	Marlette Lake	3.57	2 stations	0.00
New England	21.8	−0.5	2 stations	55	27	St. Albans, Vt	−32	25	2.85	−0.53	Kingston, R. I	4.86	Bethleham, N. H	0.76
New Jersey	31.6	+1.8	Tuckerton	64	27	Layton	−5	[1] 2	2.16	−1.46	Bayonne	4.35	Newton	1.37
New Mexico	31.9	−0.9	Fort Sumner	72	31	Gavilan	−22	5	0.45	−0.09	Carson Seep Ranger station.	1.93	5 stations	0.00
New York	23.6	+1.0	2 stations	57	27	2 stations	−27	24	2.42	−0.49	Gabriels	4.68	Ogdensburg	0.64
North Carolina	41.0	−0.2	3 stations	75	[1] 25	Louisburg	1	16	2.21	−1.66	Beaufort	4.05	Elizabeth City	0.50
North Dakota	21.4	+15.2	Carson	68	29	Towner	−31	13	0.15	−0.32	Steele	0.91	4 stations	0.00
Ohio	31.8	+3.9	2 stations	66	25	2 stations	−2	15	1.23	−1.68	Jefferson	2.42	Chillicothe	0.58
Oklahoma	42.1	+4.0	Chandler	78	30	Pawhuska	8	14	0.64	−0.76	Hennessey	1.23	2 stations	0.00
Oregon	34.7	+3.5	2 stations	72	[1] 28	Austin	−11	8	2.63	−1.03	Valsetz	17.70	Bear Creek	T.
Pennsylvania	30.0	+2.1	Hyndman	65	25	Gouldsboro	−12	23	1.46	−1.79	Pleasant Mount	2.66	2 stations	0.49
South Carolina	44.5	−1.0	Yemassee	76	31	Clemson College	10	16	2.58	−0.92	Pinopolis	3.55	Darlington	1.42
South Dakota	28.6	+13.1	Academy	72	29	La Delle	−22	14	0.23	−0.40	Hardy Ranger station.	1.11	9 stations	T.
Tennessee	39.5	+0.8	Hall's Hill	74	30	Rogersville	−2	16	1.83	−2.91	Rugby	2.90	Bristol	0.47
Texas	48.5	+0.3	Presidio	85	31	Dalhart	8	11	2.81	+0.99	Bon Wier	7.49	Pampa	0.06
Utah	22.4	−2.3	St. George	72	29	Duchesne	−18	10	0.39	−0.87	Silver Lake	1.52	2 stations	0.00
Virginia	38.1	+2.0	Diamond Springs	73	28	Callaville	−2	16	1.58	−1.77	Diamond Springs	3.09	Monterey	0.27
Washington	35.7	+6.2	2 stations	70	[1] 28	Bumping Lake	−2	7	6.68	+0.83	Wynoochee Oxbow	31.80	Irene Mountain	0.84
West Virginia	33.7	+1.7	Cairo	71	25	2 stations	−10	2	1.37	−2.49	Pickens	4.09	Upper Tract	0.65
Wisconsin	23.9	+9.9	Big St. Germain Dam.	52	6	Hillsboro	−21	21	0.69	−0.47	Mauston	1.62	Amery	0.08
Wyoming	23.6	+5.1	2 stations	71	29	Buffalo Ranch	−25	20	0.24	−0.64	Bechler River	2.30	6 stations	0.00
Alaska (December)	14.9	+9.5	Mile Seven (Cordova).	58	1	Rampart	−39	15	3.94	+1.33	Ketchikan	35.16	Rampart	0.13
Hawaii	69.5	+1.0	Waipahu	88	14	Volcano Observatory.	43	21	2.08	−7.28	Kukaua	9.74	12 stations	0.00
Porto Rico	74.3	+1.0	San German	94	6	Guineo Reservoir	46	9	1.54	−2.04	Rio Blanco	9.98	Santa Rita (No. 3)	0.00

[1] Other dates also.

TABLE 1.—*Climatological data for Weather Bureau stations, January, 1931*

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with .01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0-10	In.	In.
New England							25.6	+1.1										72	3.04	−0.4										5.1		
Eastport	76	67	85	29.77	29.86	−0.14	21.8	+1.4	42	13	30	−6	25	14	38	20	15	74	2.90	−1.1	14	8,321	nw.	52	e.	6	11	4	16	6.2	12.2	2.4
Greenville, Me.	1,070	6		28.67	29.89		13.8		40	27	23	−13	24	4	33				2.97		9	5,961	nw.				14	11	6		29.8	
Portland, Me.	103	82	117	29.80	29.93	−.12	25.2	+2.8	47	4	33	1	25	18	24	21	14	64	3.22	−0.8	10	5,693	w.	25	ne.	6	17	6	8	4.1	16.0	9.6
Concord	289	70	79	29.59	29.92	−.13	21.9	+0.3	50	27	32	−8	23	12	45				1.73	−1.3	7	3,857	nw.	21	nw.	7	14	8	9	4.5	20.3	16.8
Burlington	403	11	48	29.50	29.97	−.08	15.8	−3.0	38	27	25	−18	25	7	46				2.49	+0.7	16	6,540	s.	38	s.	25	4	12	15	6.9	31.3	16.0
Northfield	876	12	60	28.98	29.97	−.08	14.0	−1.2	44	27	26	−24	25	2	57	12	9	84	1.91	−0.4	10	3,819	n.	23	nw.	7	6	14	11	6.2	23.2	16.5
Boston	125	106	165	29.79	29.94	−.11	30.6	+2.7	55	27	38	7	15	23	27	26	20	65	4.09	+0.5	8	5,804	nw.	22	ne.	6	14	12	5	4.2	11.7	7.4
Nantucket	12	14	90	29.90	29.91	−.13	33.0	+1.7	53	6	40	14	25	26	26	30	26	79	3.23	−0.5	10	10,509	w.	42	ne.	5	9	7	15	5.9	5.9	4.0
Block Island	26	11	46	29.91	29.94	−.13	32.2	+1.2	52	6	38	11	15	26	26	29	24	71	3.81	0.0	9	13,341	w.	50	w.	7	12	11	8	5.3	4.6	2.2
Providence	160	215	251	29.76	29.95	−.11	29.8	+2.6	51	27	37	9	15	22	26	26	19	65	3.42	−0.3	8	8,340	nw.	40	nw.	7	16	9	6	4.2	12.0	7.0
Hartford	159	122		29.79	29.98	−.09	27.9	+2.4	53	27	35	5	15	21	24				3.46	−0.5	7		nw.				12	13	6	4.3	12.9	7.5
New Haven	106	74	153	29.86	29.98	−.10	29.7	+1.5	48	4	37	7	15	23	20	26	21	70	3.17	−0.8	7	5,693	nw.	28	nw.	7	16	10	5	4.1	2.5	2.0
Middle Atlantic States							34.9	+2.5										70	1.87	−1.4										5.3		
Albany	97	107	115	29.89	30.00	−.07	24.0	+0.9	45	27	32	−2	25	16	33	21	16	72	2.26	−0.1	7	4,555	s.	19	s.	25	7	16	8	5.5	14.7	9.2
Binghamton	871	10	84	29.04	30.00	−.08	24.8	+0.7	48	27	33	−1	2	16	33				2.19	−0.3	15	4,100	nw.	22	nw.	7	4	7	20	7.7	15.7	4.8
New York	314	414	454	29.65	30.00	−.10	33.2	+2.3	55	27	40	11	15	26	23	29	22	64	2.43	−1.2	6	11,747	nw.	51	nw.	6	9	14	8	5.3	0.7	0.0
Bellefonte	1,050	5	36	28.87	30.02		28.0		51	25	37	1	3	19	42	24	21	81	1.01		9		sw.	36	w.	21	4	12	15	6.8	4.6	0.0
Harrisburg	374	94	104	29.64	30.05	−.05	33.1	+4.1	56	27	40	14	15	27	25	28	21	64	1.82	−1.3	5	4,795	w.	26	w.	31	10	12	9	5.5	1.5	0.0
Philadelphia	114	123	367	29.90	30.04	−.07	36.2	+3.6	56	27	42	16	15	30	19	31	22	57	2.17	−1.1	4	8,903	nw.	40	nw.	7	11	8	12	5.2	0.1	0.0
Reading	325	81	98	29.67	30.04		33.2	+3.8	56	27	40	13	15	26	24	29	23	68	2.16	−1.4	4	4,297	nw.	28	e.	5	11	12	8	5.3	0.3	0.0
Scranton	805	111	119	29.13	30.02	−.07	27.8	+1.2	50	27	35	7	2	20	26	25	20	76	1.37	−1.7	10	4,558	sw.	25	nw.	31	4	15	12	6.3	4.5	T.
Atlantic City	52	37	172	29.96	30.02	−.09	36.1	+3.6	54	27	43	16	16	29	24	31	26	71	2.06	−1.4	4	11,147	w.	44	e.	5	13	7	11	4.9	0.0	0.0
Cape May	17	13	49				36.5	+2.4	59	27	44	18	15	30	21	33	29	82	1.71	−1.7	6		nw.				15	7	9		T.	0.0
Sandy Hook	22	10	55	29.96	29.99		32.9		52	27	39	14	15	27	19	29	24	73	2.27	−1.7	5	10,372	nw.	44	nw.	6	18	6	7	4.1	0.6	0.0
Trenton	190	159	183	29.81	30.02		33.2	+2.7	60	27	41	14	15	26	28	29	22	66	2.15	−1.2	4	6,918	nw.	35	nw.	7	11	11	9	5.1	T.	0.0
Baltimore	123	100	215	29.90	30.04	−.08	38.1	+4.3	64	27	45	19	16	31	26	32	26	64	1.89	−1.6	5	6,547	sw.	36	w.	31	12	9	10	4.9	1.1	0.0
Washington	112	62	85	29.92	30.05	−.08	37.0	+3.6	64	27	45	16	16	29	27	31	24	62	1.56	−2.0	5	4,128	nw.	30	nw.	7	11	9	11	5.5	T.	0.0
Cape Henry	18	8	54	30.03	30.05		41.4	+1.2	69	27	48	22	16	35	24	37	33	78	1.62	−1.5	6	8,078	sw.	38	nw.	15	14	6	11	4.7	0.4	0.0
Lynchburg	681	153	188	29.31	30.07	−.06	40.5	+3.0	67	25	50	15	16	31	36	34	28	64	1.48	−2.0	5	5,018	w.	29	nw.	6	18	2	11	4.8	1.4	0.0
Norfolk	91	170	205	29.97	30.07	−.06	42.4	+1.8	67	27	50	20	16	34	27	36	30	67	1.57	−1.5	5	8,287	nw.	36	nw.	6	15	3	13	4.7	2.5	0.0
Richmond	144	11	52	29.91	30.07	−.07	39.7	+1.8	65	27	50	10	16	29	38	34	29	72	1.88	−1.3	4	4,743	sw.	27	sw.	30	15	9	7	4.3	1.5	0.0
Wytheville	2,304	49	55	27.63	30.09	−.05	35.2	+2.2	56	25	43	9	2	28	38	30	25	71	1.03	−2.0	8	5,574	w.	26	w.	30	13	9	9	4.7	2.1	0.0
South Atlantic States							46.1	+0.5										71	2.39	−1.2										4.8		
Asheville	2,253	89	104	27.70	30.14	−.01	38.1	+2.7	64	30	48	14	16	28	38	32	27	70	1.84	−1.3	5	5,620	nw.	27	se.	5	14	10	7	4.3	2.6	0.0
Charlotte	779	55	62	29.24	30.10	−.05	42.4	+1.2	67	25	52	20	15	33	30	36	30	68	2.37	−1.6	7	3,351	sw.	23	sw.	5	12	6	13	5.1	2.0	0.0
Greensboro	886	5	56	29.11	30.10		37.3		66	25	49	3	16	26	41	31	27	79	1.51		6	4,789	sw.	26	sw.	5	13	5	13	5.1	5.0	0.0
Hatteras	11	5	50	30.05	30.06	−.08	46.0	−1.1	64	5	53	30	16	39	25	42	38	80	2.86	−1.6	9	9,005	w.	48	n.	14	15	6	10	4.6	0.0	0.0
Raleigh	376	103	146	29.67	30.09	−.04	43.4	+2.3	72	25	52	20	16	35	29	36	30	65	2.08	−1.6	6	5,248	sw.	30	nw.	6	15	5	11	4.8	4.0	0.0
Wilmington	78	81	91	30.04	30.12	−.02	47.0	+0.5	72	25	56	24	16	38	27	40	35	71	2.07	−1.2	8	3,914	w.	24	w.	6	14	9	8	4.6	T.	0.0
Charleston	48	11	92	30.07	30.12	−.03	49.0	−0.9	72	31	57	30	15	41	25	42	37	72	2.37	−0.6	9	5,934	w.	30	w.	14	14	7	10	5.0	0.0	0.0
Columbia, S. C.	351	41	57	29.73	30.13	−.02	46.2	+0.2	70	25	56	24	2	37	31	39	32	67	2.41	−1.0	6	4,281	w.	34	sw.	5	13	11	7	4.7	T.	0.0
Due West	711	10	55	29.34	30.14		42.8		68	31	53	19	15	33	31				2.25		7	5,924	w.	33	sw.	5	14	8	9	4.6	1.1	0.0
Greenville, S. C.	1,039	139	146	28.97	30.09		44.1	+3.8	67	31	53	24	15	35	29	38	32	70	2.55	−2.3	7	4,939	sw.	34	sw.	5	14	6	11	4.7	3.5	0.0
Augusta	182	62	77	29.92	30.12	−.04	46.5	−0.5	71	28	57	23	16	36	35	40	36	76	2.23	−1.7	6	3,297	nw.	27	sw.	5	13	10	8	4.7	T.	0.0
Savannah	65	150	194	30.05	30.12	−.03	50.8	−0.6	72	31	60	28	15	42	27	43	36	67	2.11	−0.7	8	8,010	w.	39	w.	14	13	6	12	5.3	0.0	0.0
Jacksonville	43	209	245	30.09	30.14	−.01	53.6	−1.8	74	28	62	29	15	45	25	46	41	71	3.36	+0.6	9	7,314	w.	37	w.	14	12	8	11	5.1	0.0	0.0
Florida Peninsula							62.3	−3.1										81	4.82	+2.4										6.4		
Key West	22	10	64	30.07	30.09	−.01	65.4	−4.1	81	19	70	48	15	60	17	61	60	86	3.98	+2.0	8	7,281	ne.	36	w.	5	8	10	13	6.4	0.0	0.0
Miami	25	124	168	30.08	30.11	−.03	63.8	−2.7	76	4	71	37	22	57	26	59	56	77	7.07	+4.6	10	7,575	n.	32	w.	6	1	9	21	7.8	0.0	0.0
Tampa	35	79	197	30.10	30.14	+.02	57.8	−2.6	75	27	67	32	15	49	26	52	48	79	3.42	+0.7	9	8,248	ne.	34	nw.	6	10	9	12	6.0	0.0	0.0
Titusville	44	5		30.09	30.14		57.5		79	12	67	32	15	48	29				3.40		6		nw.				8	15	8	5.6	0.0	0.0
East Gulf States							47.7	−0.4										71	3.31	−1.4										5.5		
Atlanta	1,173	190	216	28.86	30.13	−.02	43.4	+0.8	64	25	50	18	15	36	27	37	31	66	2.61	−2.3	10	7,436	nw.	32	nw.	14	12	3	16	5.9	0.1	0.0
Macon	370	78	87	29.74	30.15	−.01	45.8	−1.0	70	28	56	21	15	35	36	39	33	68	2.89	−1.3	8	3,791	nw.	24	sw.	5	12	6	13	5.7	T.	0.0
Thomasville	273	49	103	29.85	30.15	−.01	50.8	−0.2	73	31	60	25	15	41	32	43	38	71	3.12	−1.0	10	4,913	nw.	33	sw.	5	10	9	12	5.5	T.	0.0
Apalachicola	36	11	51	30.11	30.15		51.4		73	29	58	20	15	44	22	47	43	80	4.36	+0.7	8	5,491	nw.	25	nw.	5	12	7	12	5.1	0.0	0.0
Pensacola	56	149	185	30.11	30.17	+.03	51.0	−1.5	72	29	58	27	15	44	22	46	41	74	3.81	−0.2	6	8,060	e.	40	w.	4	8	11	12	5.7	0.0	0.0
Anniston	741	9	57	29.35	30.17	+.01	42.8	+0.6	67	25	53	18	15	32	37				2.49	−2.7	8	3,278	nw.	22	sw.	5	14	4	13	4.9	T.	0.0
Birmingham	700	11	48	29.38	30.17	+.01	45.4	+0.3	69	28	54	18	15	37	31	38	33	68	2.15	−3.4	9	4,363	nw.	28	se.	4	13	4	14	5.3	T.	0.0
Mobile	57	125	161	50.10	30.16	+.01	50.6	−0.9	74	29	59	27	15	42	31	45	41	77	5.43	+0.6	8	5,498	n.	34	sw.	4	9	12	10	5.2	0.0	0.0
Montgomery	223	100	112	29.92	30.18	+.02	47.6	−0.6	72	28	57	23	15	39	31	41	34	66	2.48	−2.7	8	3,731	nw.	22	nw.	14	10	9	12	5.4	T.	0.0
Corinth	469	6					42.6		69	25	53	14	15	32	37				2.31		7		se.				11	12	8		0.5	0.0
Meridian	375	87	95	29.76	30.17	+.01	46.2	−0.8	74	28	56	20	15	36	36	40	34	72	2.66	−2.7	5	3,097	ne.	27	sw.	5	12	7	12	5.2	0.0	0.0
Vicksburg	247	65	73	29.91	30.20	+.05	48.4	+0.2	72	29	56	23	15	40	26	42	35	68	3.04	−2.3	6	4,206	nw.	26	nw.	5	10	5	16	6.0	0.0	0.0
New Orleans	53	76	84	30.11	30.17	+.04	52.5	−1.7	72	28	59	30	15	46	22	47	41	71	4.65	+0.3	7	3,987	ne.	24	sw.	4	10	7	14	5.7	0.0	0.0
West Gulf States							50.4	+2.2										76	3.35	+0.6										5.8		
Shreveport	249	77	93	29.90	30.19	+.05	49.1	+2.1	71	29	57	24	14	41	28	44	41	79	3.58	−0.4	8	3,955	s.	22	w.	5	8	13	10	5.3	0.0	0.0
Bentonville	1,303	11	44	28.72	30.12	−.02	39.8	+5.7	70	30	49	8	14	30	34				0.61		7	3,009	nw.	17	nw.	12	21	1	9		0.3	0.0
Fort Smith	457	79	94	29.66	30.15	+.01	43.1	+3.6	70	30	53	16	14	34	35	38	32	72	0.48	−2.1	5	4,963	e.	32	w.	13	12	8	11	5.2	0.4	0.0
Little Rock	357	136	153	29.78	30.17	+.02	44.1	+2.7	74	30	52	20	14	36	34	38	31	64	1.00	−3.7	5	5,056	nw.	32	w.	13	10	9	12	5.3	T.	0.0
Austin	605	136	148	29.52	30.16		51.4	+1.9	75	31	60	28	14	46	34	47	43	79	4.30	+2.2	11	4,316	n.	28	nw.	4	8	5	18	6.3	0.0	0.0
Brownsville	57	83	100	30.06	30.12		60.0	+0.2	77	4	67	41	21	53	25	56	53	85	4.56	+3.1	14	6,075	e.	27	nw.	4	4	12	15	7.0	0.0	0.0
Corpus Christi	20	11	78	30.13	30.15	+.06	57.0	+1.0	75	4	63	39	21	51	26	53	50	83	2.29	+0.7	10	6,588	e.	30	nw.	4	4	10	17	6.9	0.0	0.0
Dallas	512	220	227	29.60	30.17		48.2		69	31	57	22	14	40	27				1.20	−1.1	8	6,893	w.	35	sw.	7	19	7	5	3.4	0.0	0.0
Fort Worth	670	106	114	29.43	30.16	+.04	49.9	+4.5	70	31	59	26	14	41	28	44	40	76	1.79	−0.3	8	4,498	sw.	22	nw.	5	12	7	12	5.5	0.0	0.0
Galveston	54	106	114	30.13	30.19	+.06	54.0	+0.2	71	31	59	37	14	49	20	50	47	81	5.58	+2.2	6	6,657	e.	32	nw.	11	6	11	14	6.4	0.0	0.0
Groesbeck	461	11	56	29.66	30.16		49.2		70	31	57	26	14	42	28				3.74	+1.0	8	5,732	n.	29	n.	13	9	10	12	5.6	0.0	0.0
Houston	138	292	314	30.03	30.18		53.8	+1.1	72	30	61	33	14	47	20				3.42	−0.3	8	7,748	se.	33	nw.	5	9	5	17	6.3	0.0	0.0
Palestine	510	64	72	29.63	30.17	+.05	50.2	+2.0	72	31	58	24	14	42	28	44	40	73	2.65	−0.8	7	4,434	s.	20	sw.	7	15	6	10	5.0	0.0	0.0
Port Arthur	34	58	66	30.13	30.17		53.4		72	31	60	34	14	46	25				6.34	+2.6	7	4,865	e.	24	nw.	5	9	7	15	6.4	0.0	0.0
San Antonio	693	242	301	29.41	30.14	+.04	52.6	+0.3	70	24	60	30	14	45	26	47	42	73	5.86	+4.4	9	7,436	ne.	40	w.	4	10	7	14	6.1	0.0	0.0
Taylor	571	38	51	29.57	30.19	+.08	50.2	+2.7	73	31	59	26	14	42	34				3.40	+1.5	10	4,260	n.	25	sw.	3	9	9	13	5.9	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, January, 1931*—Continued

District and station	Elevation of instruments			Pressure			Temperature of the air												Precipitation			Wind									
	Barometer above sea level	Thermometer above ground	Anemometer above ground	Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. ÷ 2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Total	Departure from normal	Days with .01, or more	Total movement	Prevailing direction	Maximum velocity: Miles per hour	Maximum velocity: Direction	Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0-10	In.	In.
Ohio Valley and Tennessee							36.6	+3.0										74	1.10	−2.6										6.2		
Chattanooga	762	190	215	29.32	30.15	−0.01	41.8	+0.6	66	24	50	17	15	33	32	36	30	68	2.72	−2.5	10	4,840	sw.	29	ne.	5	12	8	11	5.2	1.6	0.0
Knoxville	995	102	111	29.05	30.14	−.01	40.0	+1.2	64	25	49	12	16	31	29	35	30	73	1.79	−2.9	10	4,074	sw.	29	sw.	5	14	6	11	4.8	7.6	0.0
Memphis	399	76	97	29.72	30.16	.00	43.6	+2.7	69	30	50	15	14	37	25	38	32	68	0.98	−3.8	6	5,479	nw.	35	nw.	13	12	6	13	5.5	T.	0.0
Nashville	546	168	191	29.57	30.17	+.01	40.8	+2.2	69	30	49	14	15	32	37	36	30	70	1.31	−3.4	9	5,400	nw.	33	nw.	14	14	5	12	4.9	0.7	0.0
Lexington	989	193	230	29.05	30.15	+.02	35.6	+2.7	60	24	42	12	1	29	28				0.77	−3.4	6	8,616	sw.	33	w.	30	10	6	15	5.8	T.	0.0
Louisville	525	188	234	29.54	30.13	−.01	37.6	+3.2	64	25	44	15	1	31	28	34	30	77	0.96	−3.0	7	6,540	sw.	26	sw.	19	10	5	16	5.8	0.2	0.0
Evansville	431	76	116	29.66	30.14	.00	37.6	+4.1	66	30	45	15	1	30	32	33	29	74	0.62	−3.1	7	5,931	sw.	24	w.	19	10	9	12	5.7	0.8	0.0
Indianapolis	822	194	230	29.18	30.09	−.03	33.4	+5.0	61	24	40	9	1	27	24	30	26	77	0.54	−2.4	6	7,156	sw.	33	w.	30	8	9	14	6.2	1.5	0.0
Royal Center	736	11	55	29.24	30.07		30.8		56	24	38	4	1	24	25				0.77	−1.5	8	6,830	sw.	31	w.	20	7	9	15	6.5	2.7	0.0
Terre Haute	575	96	129	29.47	30.10		34.6		61	24	42	9	1	28	26	31	27	79	0.95	−1.8	4	5,730	s.	27	w.	20	9	5	17	6.0	1.9	0.0
Cincinnati	627	11	51	29.41	30.11	−.01	35.3	+5.0	64	25	42	11	1	28	27	31	27	77	0.97	−2.5	6	5,090	sw.	26	sw.	30	8	6	17	6.6	0.6	0.0
Columbus	822	216	230	29.18	30.08	−.03	33.0	+4.4	58	25	40	13	15	26	23	30	26	77	0.88	−2.2	8	7,457	sw.	34	w.	30	5	10	16	6.8	1.4	T.
Dayton	899	137	173	29.10	30.09		33.8	+4.3	59	24	40	10	1	28	22	30	26	78	0.97	−2.3	5	6,054	sw.	30	w.	30	6	6	19	7.2	2.0	0.0
Elkins	1,947	59	67	27.98	30.13	+.01	30.6	+0.2	59	25	41	−7	2	20	55	27	24	81	1.36	−2.4	16	4,362	w.	33	e.	5	2	6	23	8.0	9.0	0.0
Parkersburg	637	77	82	29.44	30.11	−.01	36.0	+3.5	65	25	44	14	2	28	32	31	26	73	0.91	−2.7	8	4,151	sw.	26	nw.	30	6	6	19	7.4	T.	0.0
Pittsburgh	842	353	410	29.14	30.07	−.04	33.2	+2.5	59	25	40	13	21	20	25	29	24	70	1.16	−1.9	13	7,682	w.	42	nw.	30	5	11	15	6.5	2.9	0.4
Lower Lake Region							27.1	+2.6										78	2.08	−0.5										7.0		
Buffalo	767	247	280	29.13	29.99	−.08	25.6	+1.0	45	25	31	7	15	20	27	24	21	82	2.99	−0.3	20	12,982	w.	52	w.	19	1	13	17	7.7	22.3	6.2
Canton	448	10	61	29.48	29.98		14.8	−1.5	39	3	24	−27	24	5	55				2.18	−0.3	13	6,040	sw.	30	e.	6	9	6	16	6.4	26.5	13.8
Ithaca	836	74	100	29.05	29.99		27.0	+2.7	50	27	34	6	22	20	28	23	19	76	1.64	−0.6	15	6,479	nw.	30	nw.	7	3	12	16	7.3	21.0	6.5
Oswego	335	71	85	29.61	30.00	−.07	24.1	+0.2	45	25	31	2	15	17	35	22	19	79	3.54	+0.6	17	7,823	s.	31	n.	31	1	3	27	8.8	41.9	18.8
Rochester	523	86	102	29.41	30.00	−.07	26.2	+1.6	49	25	32	9	24	21	37	24	19	75	2.91	0.0	21	6,548	w.	26	sw.	19	1	10	20	7.8	28.7	12.0
Syracuse	596	65	79	29.33	29.99	−.08	25.8	+2.8	46	25	32	5	15	20	35				2.70	−0.3	16	4,894	w.	22	nw.	29	5	8	18	7.5	18.5	9.2
Erie	714	130	166	29.22	30.02	−.06	28.8	+2.0	52	25	34	14	21	23	22	26	23	79	1.68	−1.1	16	9,854	sw.	33	sw.	19	8	7	16	6.4	10.8	T.
Cleveland	762	267	337	29.18	30.03	−.06	31.6	+5.1	56	25	38	13	21	25	23	28	23	72	1.47	−1.0	15	10,272	sw.	40	w.	31	5	11	15	6.9	3.8	T.
Sandusky	629	5	67	29.35	30.05	−.04	30.6	+4.3	55	25	38	7	15	24	21				1.73	−0.5	12	6,479	sw.	27	sw.	25	7	10	14	6.5	4.3	T.
Toledo	628	208	243	29.35	30.05	−.04	30.6	+4.8	53	25	37	10	21	24	23	27	23	75	1.73	−0.4	11	9,335	sw.	35	sw.	20	11	5	15	5.9	3.7	0.0
Fort Wayne	856	100	119	29.10	30.06		31.4	+4.5	54	24	38	10	15	25	21	28	25	80	0.67	−1.7	5	6,775	sw.	34	nw.	30	8	10	13	6.3	2.3	T.
Detroit	730	218	258	29.22	30.04	−.04	28.4	+4.0	49	25	34	10	21	23	22	27	25	87	1.68	−0.4	13	7,708	sw.	28	sw.	16	8	7	16	6.5	14.3	T.
Upper Lake Region							25.3	+6.4										83	1.26	−0.7										7.5		
Alpena	609	13	92	29.30	30.00	−.04	23.0	+3.9	41	26	30	3	21	16	24	21	18	82	1.29	−0.6	16	6,976	nw.	29	se.	24	1	9	21	8.1	15.4	4.4
Escanaba	612	54	60	29.30	29.99	−.06	22.4	+7.0	36	16	29	−3	21	16	25	21	18	82	0.83	−0.7	10	6,148	nw.	25	n.	28	4	8	19	7.4	13.3	7.0
Grand Haven	632	54	89	29.30	30.00	−.07	29.2	+4.9	45	24	34	10	21	24	21	28	26	86	2.39	0.0	13	7,872	sw.	31	w.	20	3	5	23	8.3	19.8	0.8
Grand Rapids	707	70	244	29.23	30.02	−.04	28.7	+4.2	46	25	34	7	21	23	19	27	24	81	1.80	−0.6	13	7,895	sw.	33	sw.	16	1	8	22	8.2	19.6	T.
Houghton	668	64	99	29.22	29.97	−.08	21.4	+6.7	38	26	28	−2	21	15	30				1.16	−1.3	14	5,567	e.	37	w.	25	1	3	27	9.2	11.9	5.3
Lansing	878	6	88	29.03	30.00		26.5	+4.1	44	25	33	4	21	20	22	25	24	94	1.34	−0.5	16	6,120	sw.	25	nw.	21	8	6	17	6.6	15.2	1.3
Ludington	637	60	66	29.27	29.99		29.2	+6.1	44	24	34	10	21	24	20	28	25	84	1.72	−0.4	14	7,405	w.	35	sw.	1	5	6	20	7.3	18.6	2.4
Marquette	734	77	111	29.15	29.97	−.07	23.6	+7.3	42	26	30	2	21	18	24	22	19	82	1.70	−0.6	18	6,429	w.	20	sw.	15	1	3	27	9.0	17.0	16.5
Port Huron	638	70	120	29.29	30.00	−.06	25.6	+3.3	45	25	32	0	15	19	27	24	22	84	1.99	+0.2	14	7,499	sw.	32	nw.	30	5	9	17	7.2	15.3	9.2
Sault Sainte Marie	614	11	52	29.28	30.01	−.02	18.4	+5.1	38	26	26	−15	21	11	29	17	15	86	0.82	−1.1	13	5,110	e.	33	nw.	25	6	6	19	7.1	9.4	9.4
Chicago	673	7	131	29.30	30.05	−.05	32.0	+8.3	52	24	38	6	21	26	23	28	24	75	0.57	−1.3	5	7,177	sw.	29	nw.	30	10	6	15	6.1	2.1	0.0
Green Bay	617	109	141	29.30	29.98	−.08	24.2	+8.5	39	16	31	−5	21	18	24	23	21	83	0.64	−0.9	7	6,661	sw.	27	sw.	16	3	6	22	8.2	7.9	1.9
Milwaukee	681	125	221	29.25	30.01	−.07	29.6	+9.0	47	24	36	1	21	24	25	27	24	78	1.04	−0.7	7	8,827	w.	31	nw.	30	9	3	19	6.6	10.1	T.
Duluth	1,133	5	47	28.73	30.00	−.09	19.8	+11.9	39	26	27	−11	21	12	29	18	16	85	0.29	−0.7	6	7,991	nw.	38	nw.	24	11	4	16	6.3	4.3	T.
North Dakota							21.4	+16.4										86	0.08	−0.4										5.6		
Moorhead	940	50	58	28.96	30.02	−.12	19.6	+15.8	52	29	28	−15	14	11	31	18	16	89	0.07	−0.6	4	5,587	s.	23	nw.	20	5	7	19	7.4	0.9	T.
Bismarck	1,674	8	57	28.17	30.03	−.10	24.6	+16.8	59	29	35	−9	13	14	30	22	18	80	0.05	−0.4	4	4,929	nw.	26	n.	12	18	4	9	4.1	0.6	T.
Devils Lake	1,478	11	44	28.36	30.00	−.12	16.6	+14.8	43	29	26	−14	14	8	35	16	15	94	0.19	−0.3	5	5,967	nw.	29	n.	20	4	7	20	7.2	2.9	1.5
Ellendale	1,457	10	56	28.39	30.01		23.8		53	29	34	−12	14	14	37				0.05	−0.4	2	8,483	nw.	35	nw.	12	6	13	12	6.3	0.1	T.
Grand Forks	833	12	67				16.2		41	29	25	−14	14	8	30	15			0.14		4		nw.	32	s.	14	9	13	9		1.4	2.2
Williston	1,878	41	48	27.97	30.02	−.09	24.6	+18.2	54	31	34	−13	13	15	33	22	19	81	0.06	−0.5	3	4,289	w.	31	w.	15	19	8	4	3.0	0.5	0.0
Upper Mississippi Valley							30.9	+9.4										79	0.59	−1.0										5.8		
Minneapolis	918	102	208	28.98	29.99		25.8	+13.1	52	26	33	−5	14	19	27				0.13	−0.7	4	7,291	nw.	28	nw.	20	5	11	15	6.5	0.9	0.0
St. Paul	837	236	261	29.06	30.00	−.11	25.3	+12.7	49	26	33	−4	14	18	29				0.13	−0.8	3	6,995	nw.	29	nw.	30	7	8	16	6.5	1.1	0.0
La Crosse	714	11	48	29.22	30.01	−.10	26.4	+10.3	48	28	34	−5	21	19	32	24	22	84	0.70	−0.4	6	3,482	s.	15	s.	26	7	6	18	6.9	8.4	T.
Madison	974	70	78	28.93	30.03	−.07	26.1	+9.4	45	24	32	−3	21	20	27	25	22	85	0.78	−0.6	6	5,550	w.	23	s.	15	7	6	18	6.6	12.4	T.
Wausau	1,247	4	62		30.00		22.3		39	30	29	−6	21	16	28				0.84	−0.4	7	3,885	w.	16	nw.	30	5	10	16		13.3	0.5
Charles City	1,015	10	51	28.94	30.06	−.08	25.5	+11.8	51	28	34	−7	21	17	37	23	20	84	0.65	−0.4	1	4,213	nw.	17	sw.	15	12	8	11	5.0	6.5	0.0
Davenport	606	71	79	29.38	30.07	−.05	31.4	+9.6	55	24	38	5	21	24	29	28	24	78	0.58	−0.8	3	6,907	sw.	31	nw.	30	12	8	11	5.4	4.3	0.0
Des Moines	861	5	90	29.14	30.08	−.06	30.3	+10.2	56	29	40	0	14	21	35	27	23	78	0.57	−0.5	3	6,426	nw.	28	s.	1	9	10	12	5.4	8.6	T.
Dubuque	700	81	96	29.26	30.05	−.07	28.6	+9.5	49	24	35	−2	21	22	29	36	24	84	0.79	−0.5	4	3,834	nw.	21	nw.	30	12	4	15	6.0	7.9	T.
Keokuk	614	64	78	29.41	30.11	−.03	33.9	+9.0	64	24	42	6	14	25	30	29	24	72	0.54	−1.0	3	5,181	sw.	22	sw.	2	11	13	7	4.8	1.2	0.0
Cairo	358	87	93	29.75	30.15	−.01	39.0	+4.1	73	30	47	9	15	31	36	34	29	72	1.77	−2.0	7	5,178	s.	29	nw.	13	11	6	14	5.7	7.3	0.0
Peoria	609	11	45	29.41	30.10	−.02	32.6	+9.5	61	24	40	6	1	25	29	28	25	82	0.48	−1.3	5	4,661	s.	21	w.	20	12	8	11	5.0	1.2	0.0
Springfield, Ill	636	5	191	29.40	30.10	−.03	34.4	+7.9	64	24	42	9	1	27	28	30	26	76	0.27	−1.8	3	8,469	s.	31	w.	20	7	10	14	6.5	0.4	0.0
Hannibal	534	74	109	29.52	30.12	−.01	35.1	+8.0	65	24	43	6	14	27	29				0.24	−1.5	4	5,977	sw.	25	sw.	2	9	13	9	5.4	0.6	0.0
St. Louis	568	265	303	29.49	30.12	−.02	37.8	+7.0	70	24	46	9	14	30	27	33	27	70	0.40	−1.9	4	8,242	sw.	27	sw.	2	11	11	9	5.1	1.5	0.0
Missouri Valley							33.9	+11.1										71	0.41	−0.6										4.0		
Columbia, Mo	784	6	84	29.26	30.12	−.01	36.1	+6.9	66	24	44	5	14	28	30				0.28	−1.6	4	5,383	sw.	22	sw.	20	13	5	13	5.5	0.4	0.0
Kansas City	963	161	181	29.06	30.13	−.02	38.2	+10.0	64	24	46	7	14	30	27	33	28	70	0.56	−0.6	4	6,838	s.	26	nw.	5	14	10	7	4.3	0.2	0.0
St. Joseph	967	11	49	29.04	30.11		35.8		65	24	45	4	14	26	29	30	26	73	0.53	−0.5	3	5,385	nw.	30	nw.	12	21	6	4	3.2	0.3	0.0
Springfield, Mo	1,324	98	104	28.70	30.14	.00	38.1	+4.6	64	24	46	5	14	30	29	33	28	73	0.63	−1.7	8	6,603	s.	25	nw.	13	19	3	9	3.6	1.2	0.0
Iola	984	11	50	29.05	30.14	.00	37.8	+8.0	69	30	47	8	14	28	36				1.06	−0.3	6	3,831	s.	18	nw.	13	13	8	10	5.2	0.2	0.0
Topeka	987	92	107				37.2	+9.6	66	30	47	6	14	28	33				0.55	−0.4	3	5,937	sw.	28	nw.	13	16	9	6	3.6	0.7	0.0
Lincoln	1,189	11	81	28.80	30.11	−.04	34.0	+11.2	66	29	45	2	14	23	37	28	23	71	0.19	−0.4	3	5,886	s.	29	nw.	19	13	13	5	4.4	1.9	0.0
Omaha	1,105	115	122	28.88	30.10	−.05	33.8	+11.9	63	29	43	1	14	24	30	28	22	67	0.38	−0.3	4	4,984	nw.	24	nw.	13	18	7	6	3.3	4.3	0.0
Valentine	2,598	47	54	27.31	30.12	.00	30.4	+11.5	63	29	42	−7	14	19	36	25	20	73	0.33	−0.2	3	5,005	w.	24	nw.	19	17	10	4	3.6	4.2	T.
Sioux City	1,135	94	164	28.84	30.10	−.05	31.2	+13.4	63	29	41	−3	14	22	36	26	22	73	0.40	−0.3	5	7,416	nw.	31	nw.	20	15	7	9	4.4	4.2	0.0
Huron	1,306	59	74	28.62	30.07	−.09	27.8	+16.5	63	29	40	−10	14	15	39	23	18	71	0.12	−0.4	4	5,668	w.	28	nw.	19	15	11	5	3.9	1.4	0.0
Pierre	1,572	70	75	28.35	30.06	−.07	30.6	+14.6	66	29	41	−2	14	20	34	26	20	68	0.24	−0.2	3	4,552	nw.	26	nw.	12	16	13	2	3.3	2.7	0.0
Yankton	1,233	49	57	28.72	30.08	−.08	31.9	+14.6	66	29	43	−2	14	21	37				0.05	−0.5	1	4,918	w.	22	nw.	13	15	10	6	4.0	0.5	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, January, 1931*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with .01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°	°F.	°F.	°F.		In.	In.		Miles								0–10	In.	In.
Northern Slope							**29.4**	**+10.1**										**68**	**0.20**	**−0.6**										**5.0**		
Billings	3,140	5	----	----	----	----	32.6	----	68	29	47	−1	18	18	45	----	----	----	0.14	----	1	----	nw.	----	----	----	12	12	7	----	2.0	----
Havre	2,505	11	44	27.34	30.05	−0.05	28.6	+15.7	57	23	39	−4	13	19	39	25	21	75	0.57	−0.2	3	7,287	sw.	32	sw.	25	9	13	9	5.0	5.0	0.0
Helena	4,124	89	113	25.82	30.13	−.02	31.8	+11.6	56	28	40	12	20	24	26	27	21	63	0.04	−0.8	3	4,447	sw.	34	sw.	28	3	8	20	7.4	0.5	0.0
Kalispell	2,973	48	56	27.02	30.17	+.05	27.8	+7.4	52	23	34	4	20	22	21	27	25	86	0.55	−1.0	10	2,251	nw.	17	w.	23	2	5	24	8.5	4.6	3.0
Miles City	2,371	48	55	27.49	30.12	.00	31.0	+16.5	66	29	43	−9	13	19	38	26	20	70	0.05	−0.6	1	3,405	s.	27	nw.	24	17	8	6	4.1	0.7	0.0
Rapid City	3,259	50	58	26.61	30.13	+.03	34.2	+12.2	70	29	46	−3	13	23	42	27	18	57	0.15	−0.3	4	4,819	w.	32	n.	26	14	12	5	3.8	2.0	0.0
Cheyenne	6,088	84	101	23.99	30.13	+.08	30.8	+5.3	59	29	41	6	9	21	35	23	13	51	0.16	−0.3	3	9,335	w.	37	sw.	26	14	13	4	3.9	1.8	T.
Lander	5,372	60	68	24.67	30.23	+.11	24.8	+6.5	60	28	38	0	10	11	37	19	13	74	T.	−0.6	0	2,147	sw.	20	sw.	16	14	13	4	3.7	T.	0.0
Sheridan	3,790	10	47	26.10	30.13	----	29.2	----	71	29	43	2	14	15	47	24	17	66	0.33	−0.5	6	2,257	nw.	28	nw.	26	10	13	8	5.0	6.0	0.0
Yellowstone Park	6,241	11	48	----	30.29	+.15	22.8	+5.2	45	28	31	5	20	15	29	----	----	72	0.11	−1.5	8	5,176	sw.	27	sw.	1	3	10	18	----	3.6	9.1
North Platte	2,821	11	51	27.11	30.13	+.01	33.3	+10.4	63	29	46	2	14	21	37	26	21	71	0.03	−0.4	3	3,972	w.	23	nw.	19	18	9	4	3.4	0.3	0.0
Middle slope							**37.3**	**+6.8**										**64**	**0.27**	**−0.5**										**4.1**		
Denver	5,292	106	113	24.74	30.13	+.08	35.8	+6.0	64	29	47	14	10	25	38	27	16	50	0.02	−0.4	1	4,454	s.	18	w.	1	17	10	4	3.6	0.1	0.0
Pueblo	4,685	80	86	25.32	30.14	+.09	32.4	+2.5	64	23	49	4	19	16	52	25	16	55	0.12	−0.2	1	3,424	nw.	25	w.	1	17	11	3	3.6	1.6	0.0
Concordia	1,392	50	58	28.63	30.15	+.01	35.9	+9.5	69	29	47	4	14	24	39	29	24	71	0.10	−0.5	2	4,629	nw.	25	nw.	19	15	12	4	3.5	0.2	0.0
Dodge City	2,509	11	51	27.49	30.17	+.06	37.5	+8.5	71	24	50	10	14	24	41	30	24	70	0.10	−0.3	3	5,052	nw.	22	nw.	18	18	8	5	3.4	0.4	0.0
Wichita	1,358	139	158	28.66	30.13	.00	39.0	+7.7	68	30	48	8	14	30	32	34	28	71	0.29	−0.5	3	6,821	s.	34	s.	24	16	8	7	4.1	0.1	0.0
Broken Arrow	765	11	56	29.31	30.15	----	41.4	----	73	30	51	13	14	32	33	----	----	----	0.57	−1.4	4	7,205	s.	33	nw.	13	11	10	10	5.2	T.	0.0
Oklahoma City	1,214	10	47	28.83	30.15	+.04	43.0	+6.6	73	30	53	15	14	33	34	36	31	70	0.70	−0.5	6	5,486	s.	23	s.	24	11	12	8	5.3	0.2	0.0
Southern Slope							**44.4**	**+1.7**										**70**	**1.67**	**+1.0**										**5.2**		
Abilene	1,738	10	52	28.31	30.16	+.07	46.4	+2.2	68	31	56	22	14	37	32	41	36	74	1.82	+0.9	9	5,198	s.	26	w.	7	8	8	15	6.1	0.0	0.0
Amarillo	3,676	10	49	26.32	30.13	+.07	40.0	+4.7	66	24	51	20	13	29	33	32	25	62	0.31	−0.2	1	5,317	sw.	22	se.	6	16	11	4	3.8	0.1	0.0
Del Rio	944	64	71	29.11	30.12	+.06	51.4	−0.9	71	7	59	31	21	43	34	47	43	79	4.12	+3.6	11	4,365	se.	44	nw.	4	8	11	12	5.9	0.0	0.0
Roswell	3,566	75	85	26.45	30.14	+.10	40.0	+0.8	65	31	52	18	1	28	39	34	27	66	0.42	−0.1	3	3,709	s.	35	w.	6	13	9	9	4.8	0.2	0.0
Southern Plateau							**42.1**	**+1.4**										**50**	**0.34**	**−0.3**										**3.2**		
El Paso	3,778	152	175	26.26	30.12	+.11	44.0	−1.0	66	24	55	23	19	33	33	36	25	53	0.83	+0.4	4	4,838	nw.	49	w.	6	17	7	7	3.6	0.0	0.0
Santa Fe	7,013	38	53	23.25	30.18	+.14	29.9	+1.1	56	28	42	7	20	18	35	22	12	53	0.25	−0.4	4	3,578	ne.	19	sw.	6	14	14	3	3.8	2.5	T.
Flagstaff	6,907	10	59	23.36	30.10	+.05	28.6	+1.9	54	28	44	−1	18	13	47	23	----	65	0.47	----	3	4,275	e.	25	e.	25	12	15	4	----	1.5	T.
Phoenix	1,108	10	107	28.88	30.05	+.02	52.9	+1.7	80	29	68	29	7	38	40	41	27	42	0.02	−0.8	2	2,915	e.	15	ne.	25	19	4	8	3.5	0.0	0.0
Yuma	141	9	54	29.92	30.07	+.02	55.6	+1.2	81	29	69	33	1	42	40	43	28	37	0.04	−0.4	2	3,782	n.	23	n.	18	23	6	2	1.9	0.0	0.0
Independence	3,957	6	27	26.07	30.16	+.09	41.4	+3.2	72	28	55	16	19	27	46	31	----	----	0.55	−0.4	5	----	nw.	----	----	----	25	2	4	----	T.	0.0
Middle Plateau							**28.4**	**+0.2**										**71**	**0.43**	**−0.6**										**4.9**		
Reno	4,532	74	81	25.55	30.20	+.07	34.8	+2.3	61	29	46	15	10	24	36	30	24	67	0.68	−0.9	4	2,162	w.	26	w.	23	12	8	11	5.0	3.8	0.0
Tonopah	6,090	12	20	----	----	----	34.5	----	57	29	42	18	10	27	23	28	21	58	0.17	----	3	----	se.	----	----	----	----	----	----	----	----	----
Winnemucca	4,344	18	56	25.73	30.23	+.07	31.4	+2.8	61	29	45	5	10	17	41	27	21	70	0.09	−0.9	4	4,407	ne.	23	sw.	2	15	8	8	4.4	0.8	0.0
Modena	5,473	10	43	24.70	30.23	+.13	23.9	−2.8	47	16	37	−2	4	10	38	21	17	81	0.57	−0.3	5	4,144	w.	22	nw.	23	14	9	8	4.6	6.8	2.6
Salt Lake City	4,360	163	203	25.78	30.30	+.15	24.1	−5.1	41	2	31	9	22	17	24	23	20	82	0.72	−0.6	8	2,498	nw.	21	nw.	16	9	10	12	5.7	9.7	9.5
Grand Junction	4,602	60	68	25.52	30.22	+.16	27.6	+3.6	57	28	40	3	7	15	37	22	15	66	0.10	−0.5	2	2,844	se.	15	se.	8	12	12	7	4.7	1.2	0.0
Northern Plateau							**32.0**	**+3.5**										**84**	**1.10**	**−0.5**										**7.8**		
Baker	3,471	48	53	26.58	30.28	+.12	26.4	+1.5	45	29	33	1	8	20	25	25	22	84	1.05	−0.3	14	3,533	se.	18	se.	23	5	5	21	7.5	9.5	0.3
Boise	2,739	79	87	27.37	30.32	+.13	30.2	+0.4	48	23	37	11	8	23	28	28	26	84	0.88	−0.8	9	2,170	se.	18	se.	25	6	5	20	7.1	5.6	0.0
Lewiston	757	40	48	29.35	30.18	+.02	38.5	+6.0	57	28	45	18	8	32	24	----	----	----	1.00	−0.5	9	2,675	e.	17	se.	25	7	6	18	7.1	0.1	0.0
Pocatello	4,477	60	68	25.62	30.33	+.13	22.8	−1.9	45	23	32	3	8	14	28	21	18	80	0.52	−0.9	7	4,784	se.	29	s.	3	7	7	17	6.4	7.0	0.5
Spokane	1,929	101	110	28.07	30.18	+.06	34.4	+6.9	58	28	39	21	21	30	21	33	30	86	1.50	−0.7	13	2,864	s.	18	s.	23	0	3	28	9.2	5.8	0.0
Walla Walla	991	57	65	29.07	30.17	+.02	38.4	+5.7	63	27	44	20	1	33	30	36	33	83	1.51	−0.4	15	2,975	s.	24	se.	22	2	3	26	9.1	0.7	0.0
Yakima	1,076	58	67	28.99	30.17	----	33.0	+5.6	59	28	38	17	7	28	25	31	29	87	1.24	0.0	12	1,568	w.	19	sw.	23	2	5	24	8.3	9.0	0.0
North Pacific Coast Region							**45.7**	**+5.4**										**83**	**6.33**	**0.0**										**8.4**		
North Head	211	11	56	29.77	30.00	−.06	47.6	+5.5	67	29	52	38	1	43	21	45	43	85	7.95	−0.8	21	12,630	se.	62	s.	22	5	3	23	8.1	0.0	0.0
Port Angeles	29	8	53	----	30.01	----	42.8	----	51	2	47	33	19	39	13	----	----	----	3.77	−0.8	21	2,834	s.	22	sw.	14	0	5	26	----	0.0	0.0
Seattle	125	215	250	29.88	30.02	−.03	45.7	+6.2	67	28	50	31	19	41	20	43	40	81	6.34	+1.4	22	5,236	s.	37	sw.	14	3	6	22	7.9	0.0	0.0
Tacoma	194	172	201	29.82	30.03	−.01	44.6	+5.8	64	22	50	30	19	40	22	----	----	----	6.13	0.0	18	4,375	s.	34	s.	22	2	4	25	8.5	0.0	0.0
Tatoosh Island	86	9	53	29.84	29.94	−.04	47.0	+5.8	57	29	50	39	15	44	12	45	44	91	17.39	+5.6	26	13,740	e.	67	s.	22	0	5	26	9.1	0.0	0.0
Medford	1,329	29	58	28.68	30.13	----	39.3	----	61	22	48	22	19	30	32	37	34	83	1.39	−1.4	14	----	s.	39	se.	4	1	8	22	8.6	0.0	0.0
Portland, Oreg.	153	68	106	29.90	30.07	−.01	44.7	+5.3	64	27	50	30	9	40	19	41	38	79	4.30	−2.3	16	3,883	se.	30	s.	5	1	6	24	8.3	0.0	0.0
Roseburg	510	75	99	29.53	30.09	−.01	44.8	+3.6	66	27	52	31	10	37	26	42	39	81	3.38	−1.9	13	2,542	s.	27	sw.	15	2	6	23	8.0	0.0	0.0
Middle Pacific Coast Region							**49.3**	**+2.0**										**80**	**4.37**	**−0.2**										**5.8**		
Eureka	62	73	89	30.04	30.11	+.01	49.8	+2.9	64	22	57	34	17	42	25	48	45	83	4.00	−3.0	15	4,196	se.	30	se.	4	6	8	17	6.7	0.0	0.0
Red Bluff	330	5	58	29.78	30.14	+.02	47.2	+1.4	75	30	56	31	19	38	35	43	38	74	6.20	+1.4	12	3,436	nw.	26	se.	1	10	6	15	6.0	0.0	0.0
Sacramento	69	106	117	30.06	30.13	+.01	47.4	+1.6	62	26	55	31	12	40	25	46	44	86	2.50	−1.2	8	3,998	se.	22	se.	7	10	8	13	5.5	0.0	0.0
San Francisco	155	208	243	29.94	30.12	+.01	52.3	+2.4	68	29	58	43	10	47	20	48	45	77	5.50	+1.0	11	3,479	se.	18	se.	7	9	8	14	5.7	0.0	0.0
San Jose	141	12	110	29.98	30.14	----	49.8	+1.5	73	29	60	31	18	40	33	----	----	----	3.56	+0.6	11	3,467	se.	23	se.	1	12	6	13	5.3	~~0.0~~	0.0
South Pacific Coast Region							**55.6**	**+3.9**										**66**	**3.41**	**+1.1**										**4.8**		
Fresno	327	89	98	29.78	30.15	+.05	48.8	+2.6	66	28	57	31	19	40	29	45	42	79	2.61	+0.9	9	2,830	e.	21	se.	7	8	9	14	6.2	0.0	0.0
Los Angeles	338	159	191	29.71	30.08	.00	60.2	+5.6	85	29	69	46	9	51	27	49	38	52	3.90	+0.8	8	3,416	ne.	18	nw.	6	18	5	8	3.7	0.0	0.0
San Diego	87	62	70	29.97	30.07	.00	57.7	+3.4	81	28	66	44	17	49	27	51	45	67	3.72	+1.7	7	3,002	nw	25	w.	5	13	11	7	4.5	0.0	0.0
West Indies																																
San Juan, P. R.	82	9	54	29.91	30.00	----	76.0	+1.0	88	21	81	68	7	71	18	----	----	----	1.67	−2.5	12	6,989	e.	32	n.	26	12	19	0	4.2	0.0	0.0
Panama Canal																																
Balboa Heights	118	6	97	----	[1]29.84	+.01	80.6	+0.7	91	11	89	69	9	72	21	----	----	[1]76	T.	−0.8	0	7,259	n.	27	n.	22	13	18	0	4.2	0.0	0.0
Cristobal	36	6	97	[2]29.83	[1]29.86	−.01	82.0	+0.5	87	5	86	74	5	78	13	75	72	[1]75	2.01	−1.5	14	10,397	n.	30	nw.	22	6	25	0	4.9	0.0	0.0
Alaska																																
Fairbanks	455	11	44	[2]28.97	[2]29.52	----	−0.8	----	36	18	10	−30	26	−11	47	−1	−5	76	0.26	----	4	1,206	n.	13	nw.	19	7	7	17	6.5	3.9	9.8
Juneau	80	11	50	[2]29.53	[2]29.62	----	37.6	----	52	31	42	25	23	34	17	36	34	86	9.14	----	28	6,114	se.	31	e.	3	0	0	31	9.7	2.6	0.0
Hawaiian Islands																																
Honolulu	38	86	100	[2]30.03	[2]30.07	----	72.3	+1.4	80	8	77	62	20	68	13	66	64	77	0.45	−3.3	11	5,352	e.	24	ne.	18	16	12	3	3.9	0.0	0.0

[1] Observations taken bihourly.

[2] Pressure not reduced to mean of 24 hours.

TABLE 2.—*Data furnished by the Canadian Meteorological Service, January, 1931*

Stations	Altitude above mean sea level, Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max.+mean min.÷2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
	Feet	*Inches*	*Inches*	*Inches*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	*Inches*	*Inches*	*Inches*
Cape Race, N. F.	99				29.9		36.5	23.4	44	7	8.06		2.0
Sydney, C. B. I.	48	29.73	29.78	−0.15	25.3	+4.8	32.6	17.9	48	−2	7.13	+2.03	31.9
Halifax, N. S.	88	29.70	29.81	−.16	24.7	+2.9	32.9	16.5	52	−5	5.82	+0.05	13.2
Yarmouth, N. S.	65	29.73	29.80	−.20	28.6	+2.3	34.7	22.6	48	7	5.18	+0.02	12.0
Charlottetown, P. E. I.	38	29.69	29.73	−.23	19.6	+2.6	27.1	12.0	46	−6	4.92	+0.96	41.5
Chatham, N. B.	28	29.69	29.73	−.24	11.4	+1.6	22.5	0.3	34	−22	2.44	−1.15	24.0
Father Point, Que.	20	29.84	29.87	−.11	10.6	+2.6	17.1	4.2	26	−10	2.50	−0.35	25.0
Quebec, Que.	296	29.60	29.94	−.08	11.4	+2.3	18.4	4.4	32	−14	3.51	−0.50	35.1
Doucet, Que.	1,236				−3.2		9.7	−16.2	28	−46	1.22		12.2
Montreal, Que.	187	29.73	29.96	−.08	14.4	+2.7	20.9	8.0	38	−8	3.20	−0.53	31.8
Ottawa, Ont.	236	29.70	29.98	−.05	12.9	+3.3	21.2	4.6	38	−20	2.08	−0.91	20.5
Kingston, Ont.	285	29.65	29.99	−.06	20.4	+3.3	28.0	12.9	38	−10	1.40	−2.05	14.C
Toronto, Ont.	379												
Cochrane, Ont.	930				1.1		10.2	−8.0	27	−36	1.58		
White River, Ont.	1,244	29.58	29.97	−.04	5.5	+5.9	18.8	−7.7	32	−35	1.59	−0.10	
London, Ont.	808				23.8		30.1	17.6	43	2	3.18		26.C
Southampton, Ont.	656	29.24	29.98	−.05	22.5	+2.1	29.4	15.7	40	0	2.70	−1.35	27.0
Parry Sound, Ont.	688	29.26	29.99	−.02	16.3	+2.5	23.9	8.7	36	−19	3.89	−0.19	38.9
Port Arthur, Ont.	644	29.25	29.98	−.09	15.1	+12.0	23.3	6.8	34	−20	1.29	+0.47	12.9
Winnipeg, Man.	760	29.13	30.00	−.11	9.9	+16.7	17.2	2.7	39	−13	0.26	−0.62	2.6
Minnedosa, Man.	1,690	28.09	29.99	−.11	13.0	+20.2	21.0	4.9	40	−15	0.25	−0.55	2.5
Le Pas, Man.	860				5.7		14.5	−3.1	34	−28	1.50		15.0
Qu'Appelle, Sask.	2,115	27.60	29.92	−.16	18.2	+22.0	27.3	9.1	50	−25	0.44	−0.06	4.4
Moose Jaw, Sask.	1,759				25.5		37.7	13.3	57	−15	0.09		0.4
Swift Current, Sask.	2,392	27.31	29.90	−.19	26.9	+23.8	38.0	15.7	58	−12	0.10	−0.54	0.8
Medicine Hat, Alb.	2,144	27.44	29.73	−.34	32.7	+27.2	43.1	22.2	66	−2	0.06	−0.51	0.6
Calgary, Alb.	3,428	26.29	29.94	−.09	31.1	+22.7	41.9	20.4	60	3	0.05	−0.48	0.5
Banff, Alb.	4,521	25.30	30.01	+.01	25.1	+13.0	32.1	18.1	51	−1	0.60	−0.59	5.3
Prince Albert, Sask.	1,450	28.34	29.99	−.10	12.2	+20.6	20.7	3.8	50	−20	0.69	−0.28	6.9
Battleford, Sask.	1,592	28.18	29.99	−.09	15.5	+21.4	25.6	5.3	48	−6	T.	−0.40	T.
Edmonton, Alb.	2,150	27.50	29.84	−.19	22.3		30.6	14.0	55	−10	T.		T.
Kamloops, B. C.	1,262												
Victoria, B. C.	230	29.73	29.99	+.02	44.3	+5.8	47.0	41.6	56	37	4.66	−0.73	0.0
Barkerville, B. C.	4,180												
Estevan Point, B. C.	20												
Prince Rupert, B. C.	170												
Hamilton, Ber.	151												

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Doucet, Que.	1,236				11.2		20.0	2.4	34	−32	1.15		11.5
Montreal, Que.	187	29.80	30.02	−.01	22.9	+4.6	28.7	17.1	40	−6	1.45	−2.20	12.5
Ottawa, Ont.	236	29.76	30.05	+.03	22.3	+5.3	29.2	15.5	40	−10	1.88	−1.03	17.9
London, Ont.	808				26.6		31.8	21.4	47	0	3.55		24.5
Southampton, Ont.	656	29.28	30.01	−.01	27.0	+0.3	32.3	21.6	42	1	2.29	−1.69	19.2
Medicine Hat, Alb.	2,144	27.52	29.82	−.15	31.7	+13.5	41.2	22.2	56	10	0.38	−0.17	1.8
Calgary, Alb.	3,428	26.37	30.03	+.09	31.7	+13.5	42.8	20.7	58	10	0.52	−0.07	5.0
Banff, Alb.	4,521	25.41	30.16	+.22	24.0	+4.9	30.5	17.5	39	4	T.	−1.21	T.
Edmonton, Alb.	2,150	27.57	29.91	−.02	26.0	+12.9	34.1	18.0	41	4	0.32	−0.38	0.7
Kamloops, B. C.	1,262	28.91	30.24	+.30	31.7	+2.8	35.8	27.6	43	18	0.34	−0.44	2.6
Estevan Point, B. C.	20				44.4		48.9	40.0	54	30	15.74		0.0
Prince Rupert, B. C.	170				43.2		46.5	40.0	53	33	15.48		0.0

○

Chart I. Departure (°F.) of the Mean Temperature from the Normal, January, 1931

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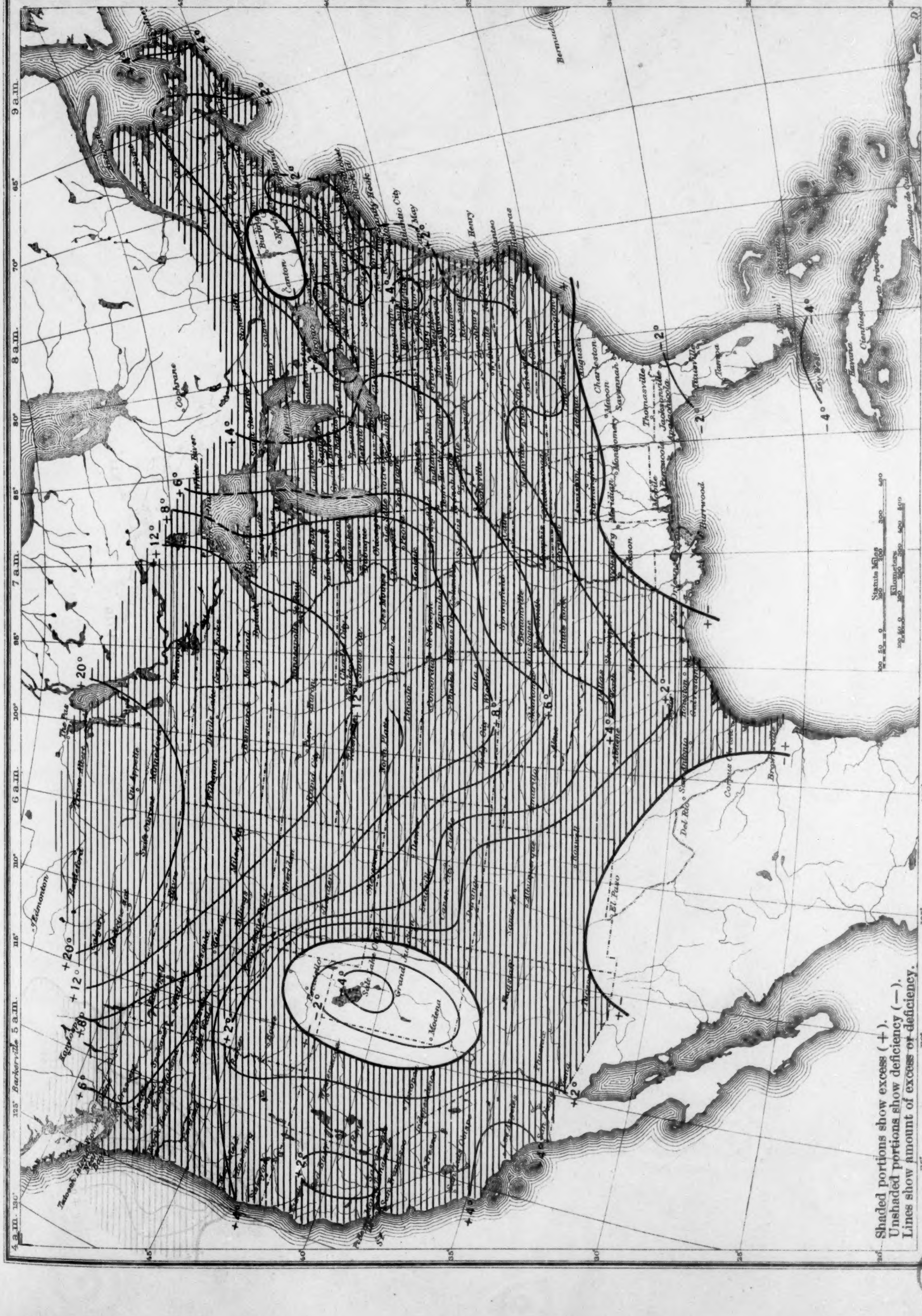
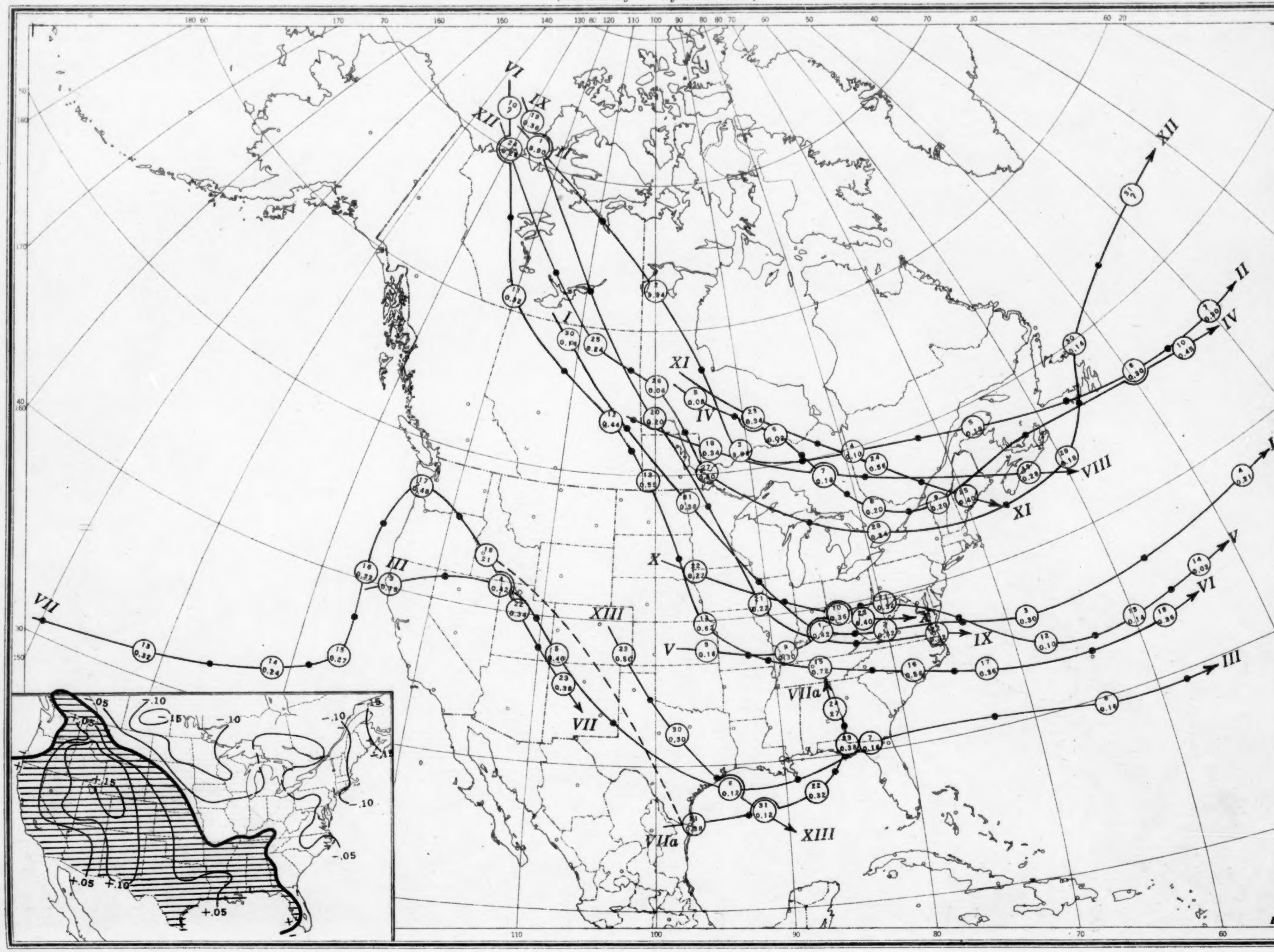


Shaded portions show excess (+).
Unshaded portions show deficiency (−).
Lines show amount of excess or deficiency.

Chart II. Tracks of Centers of Anticyclones, January, 1931. (Inset) Departure of Monthly Mean Pressure from Normal

(Plotted by Welby R. Stevens)



Circle indicates position of anticyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of anticyclone at 8 p. m. (75th meridian time).

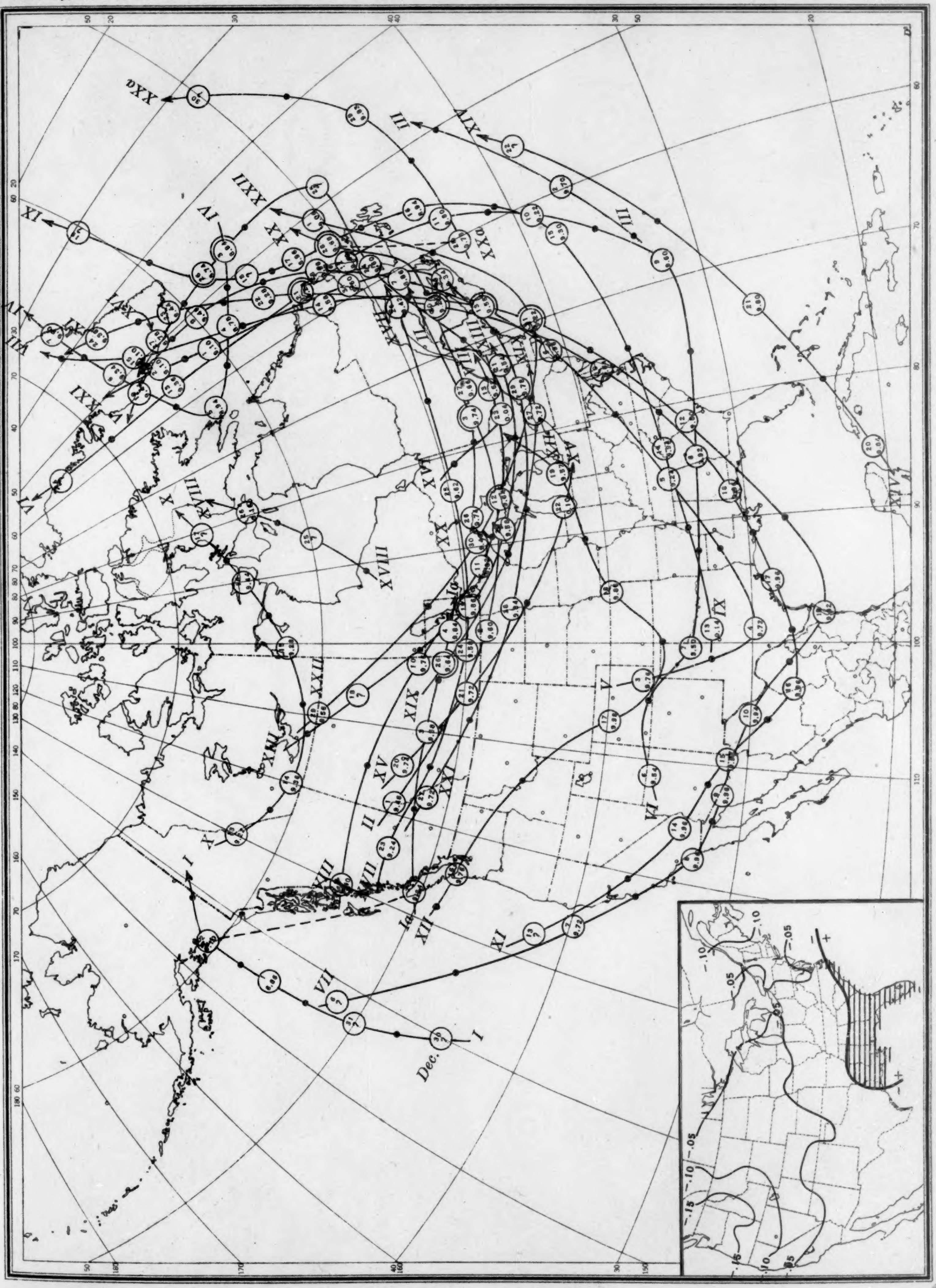
Chart III. Tracks of Centers of Cyclones, January, 1931. (Inset) Change in Mean Pressure from Preceding Month

(Plotted by Welby R. Stevens)

Circle indicates position of anticyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of anticyclone at 8 p. m. (75th meridian time).

Chart III. Tracks of Centers of Cyclones, January, 1931. (Inset) Change in Mean Pressure from Preceding Month

(Plotted by Welby R. Stevens)



Circle indicates position of cyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of cyclone at 8 p. m. (75th meridian time).

Chart IV. Percentage of Clear Sky between Sunrise and Sunset, January, 1931

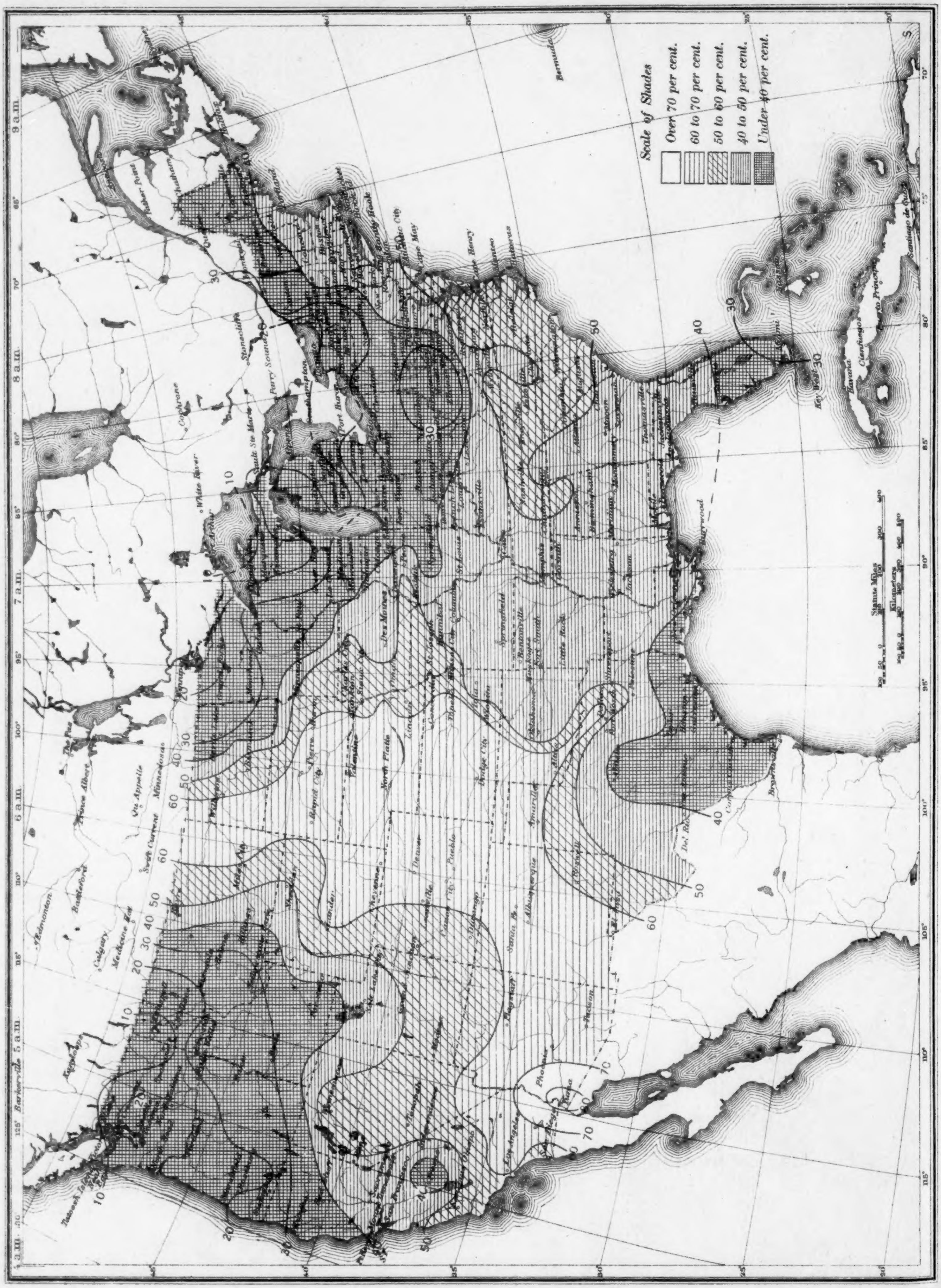


Chart V. Total Precipitation, Inches, January, 1931. (Inset) Departure of Precipitation from Normal

Chart V. Total Precipitation, Inches, January, 1931. (Inset) Departure of Precipitation from Normal

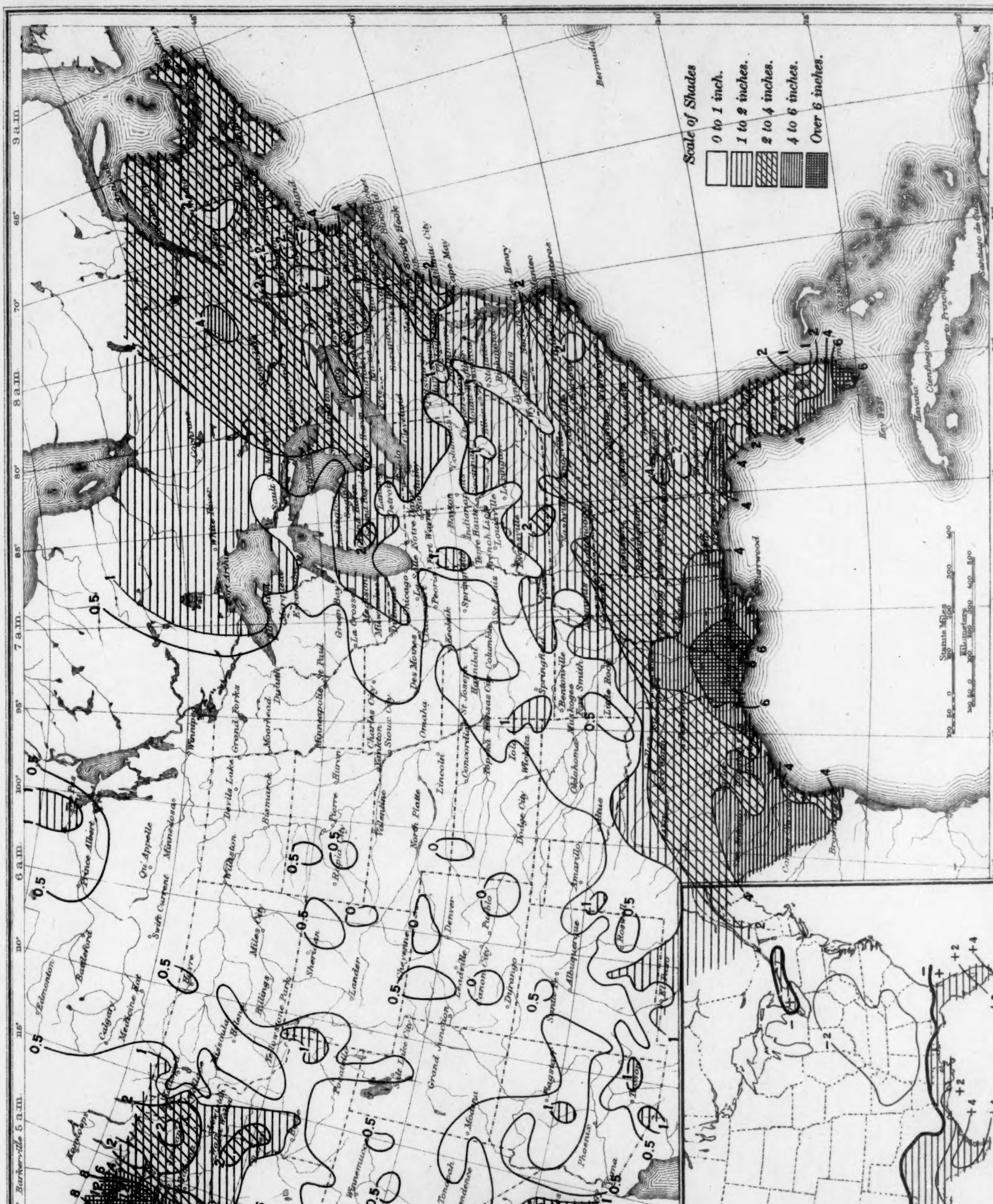


Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, January, 1931

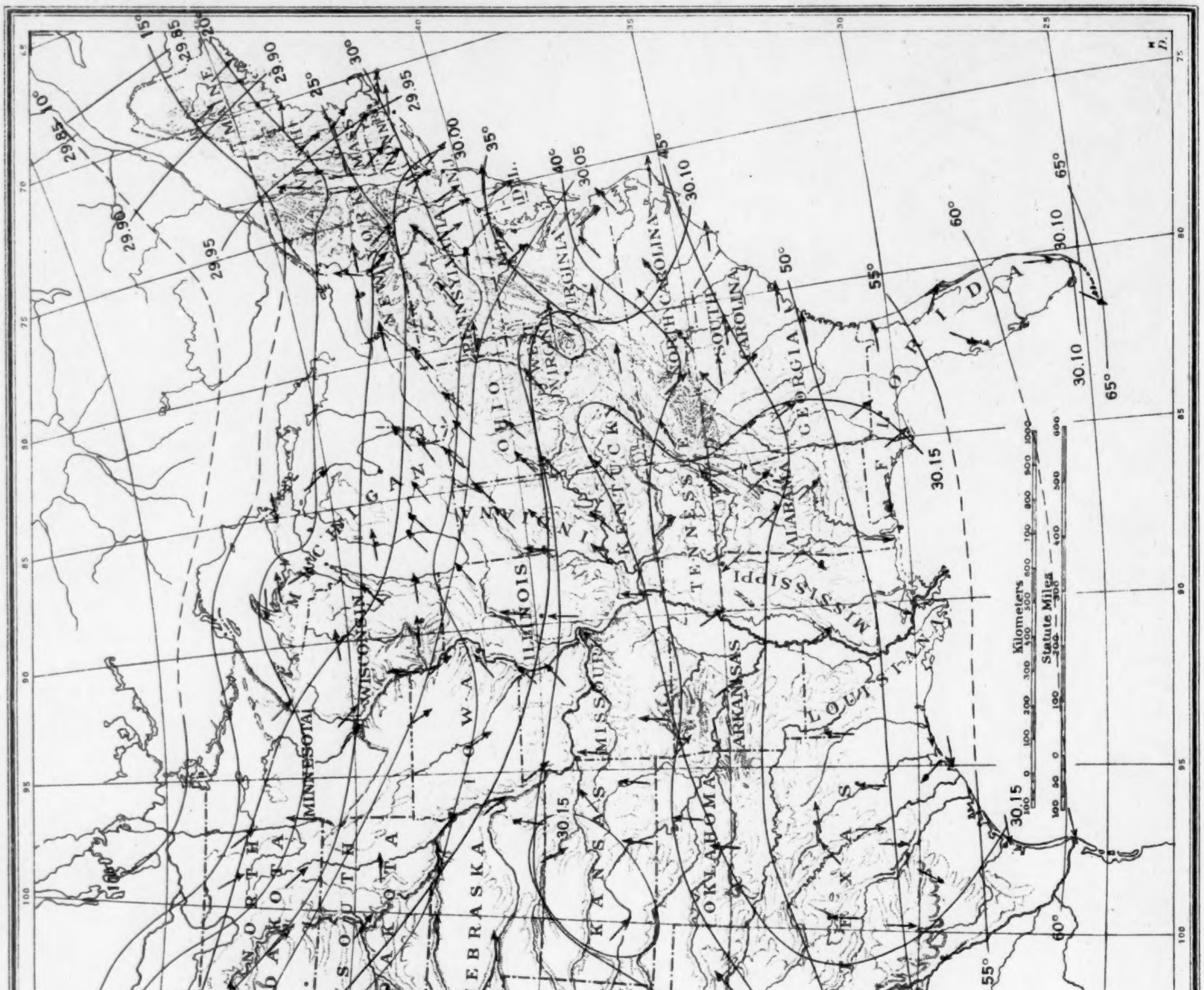


Chart VII. Total Snowfall, Inches, January, 1931. (Inset) Depth of Snow on Ground at end of Month

Chart VII. Total Snowfall, Inches, January, 1931. (Inset) Depth of Snow on Ground at end of Month

Chart VIII. Weather Map of North Atlantic Ocean, January 1, 1931

Chart VIII. Weather Map of North Atlantic Ocean, January 1, 1931

(Plotted by F. A. Young)

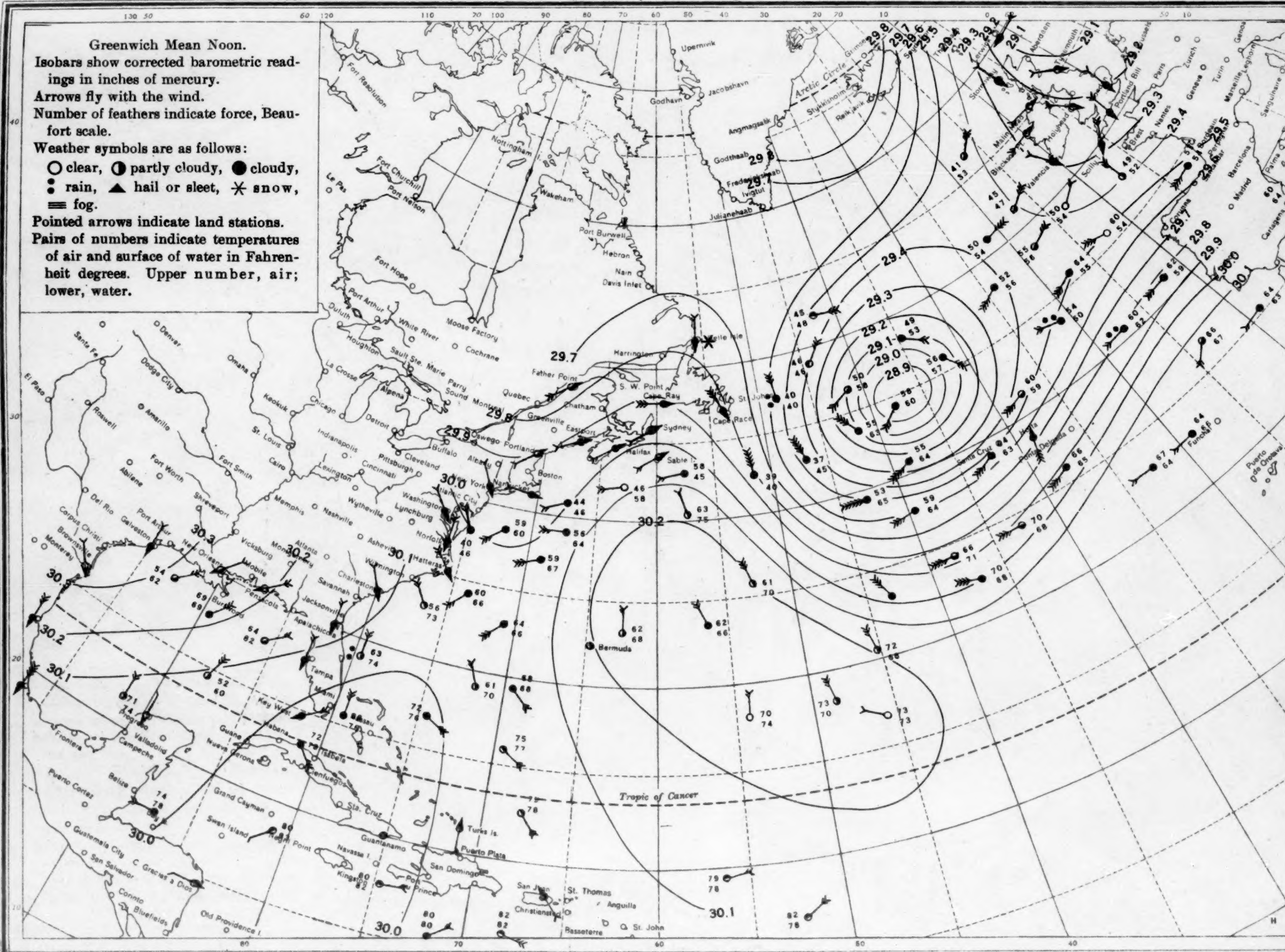


Chart IX. Weather Map of North Atlantic Ocean, January 2, 1931

(Plotted by F. A. Young)

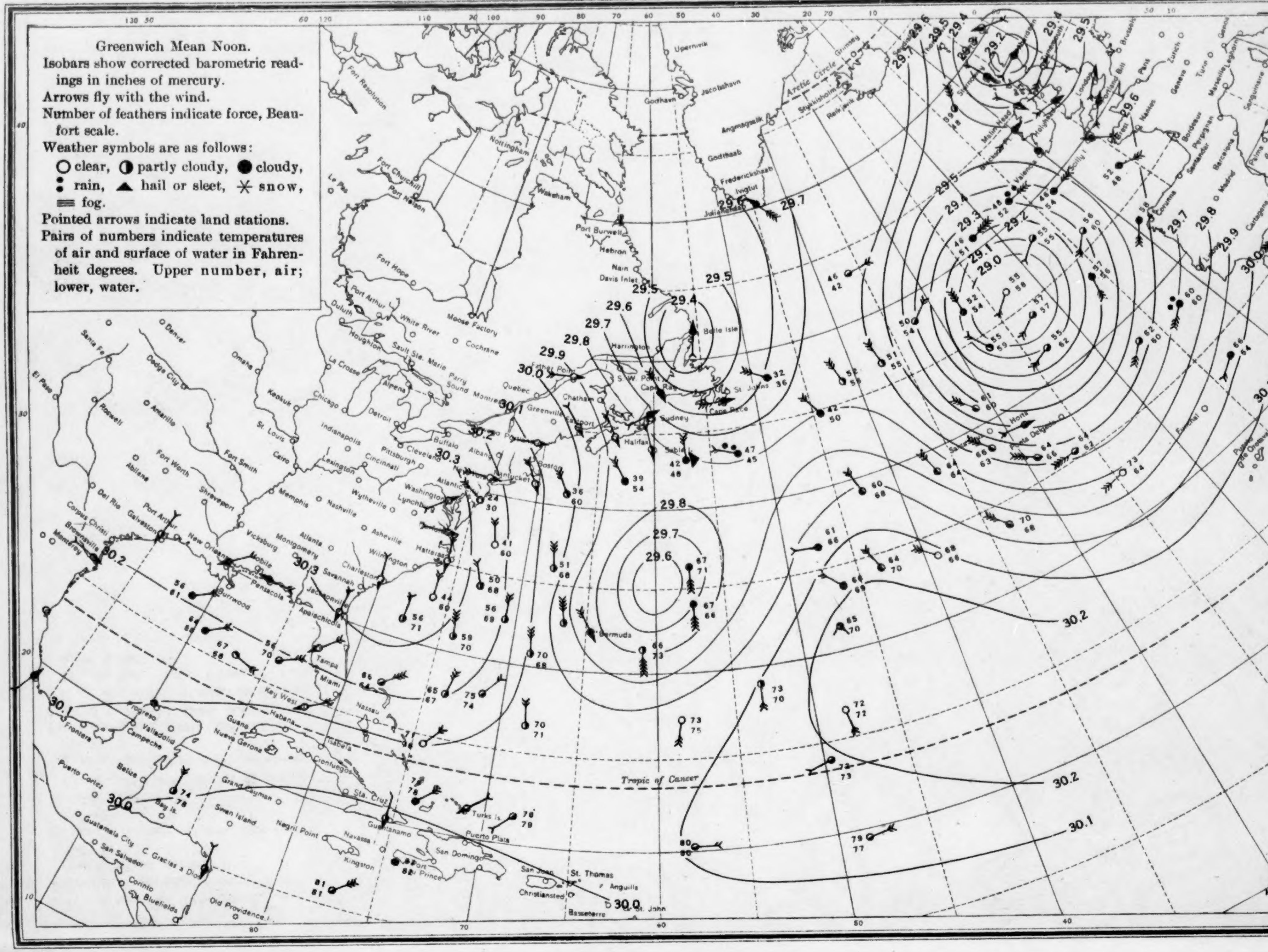
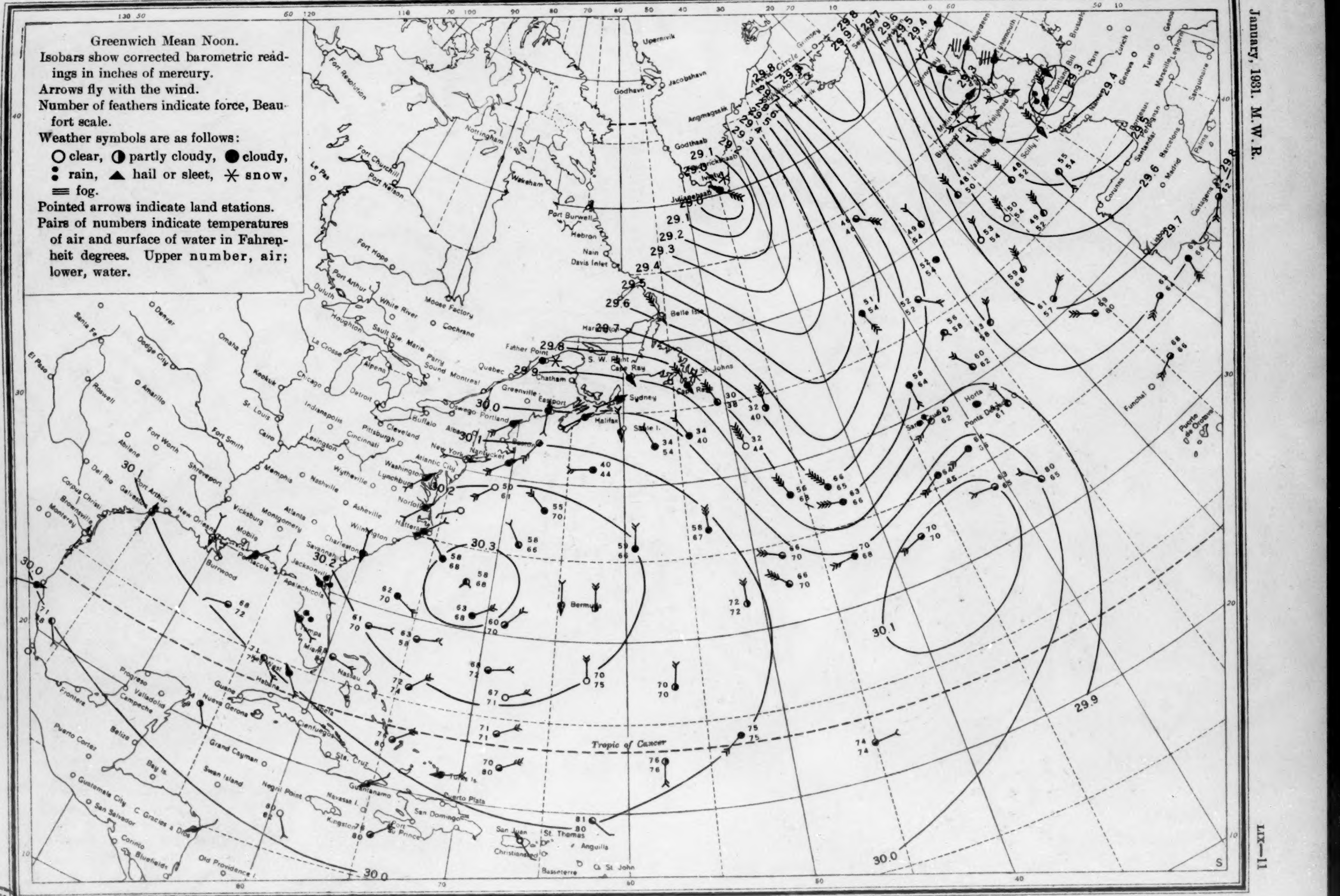


Chart X. Weather Map of North Atlantic Ocean, January 3, 1931

(Plotted by F. A. Young)



Greenwich Mean Noon.

Isobars show corrected barometric readings in inches of mercury.

Arrows fly with the wind.

Number of feathers indicate force, Beaufort scale.

Weather symbols are as follows:

○ clear, ◑ partly cloudy, ● cloudy, ⁝ rain, ▲ hail or sleet, ✳ snow, ≡ fog.

Pointed arrows indicate land stations.

Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.

Chart XI. Weather Map of North Atlantic Ocean, January 4, 1931

(Plotted by F. A. Young)

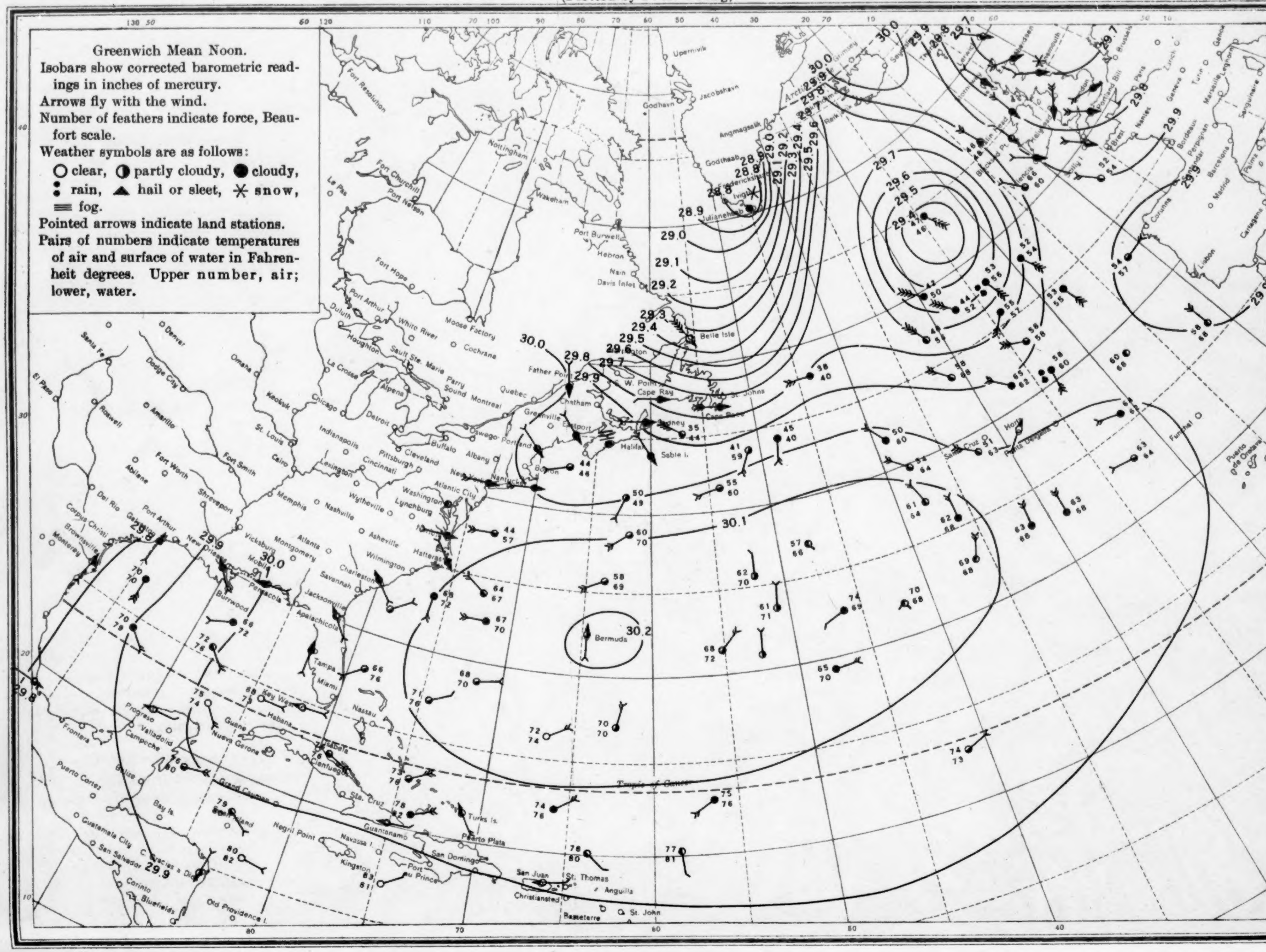


Chart XII. Weather Map of North Atlantic Ocean, January 10, 1931

(Plotted by F. A. Young)

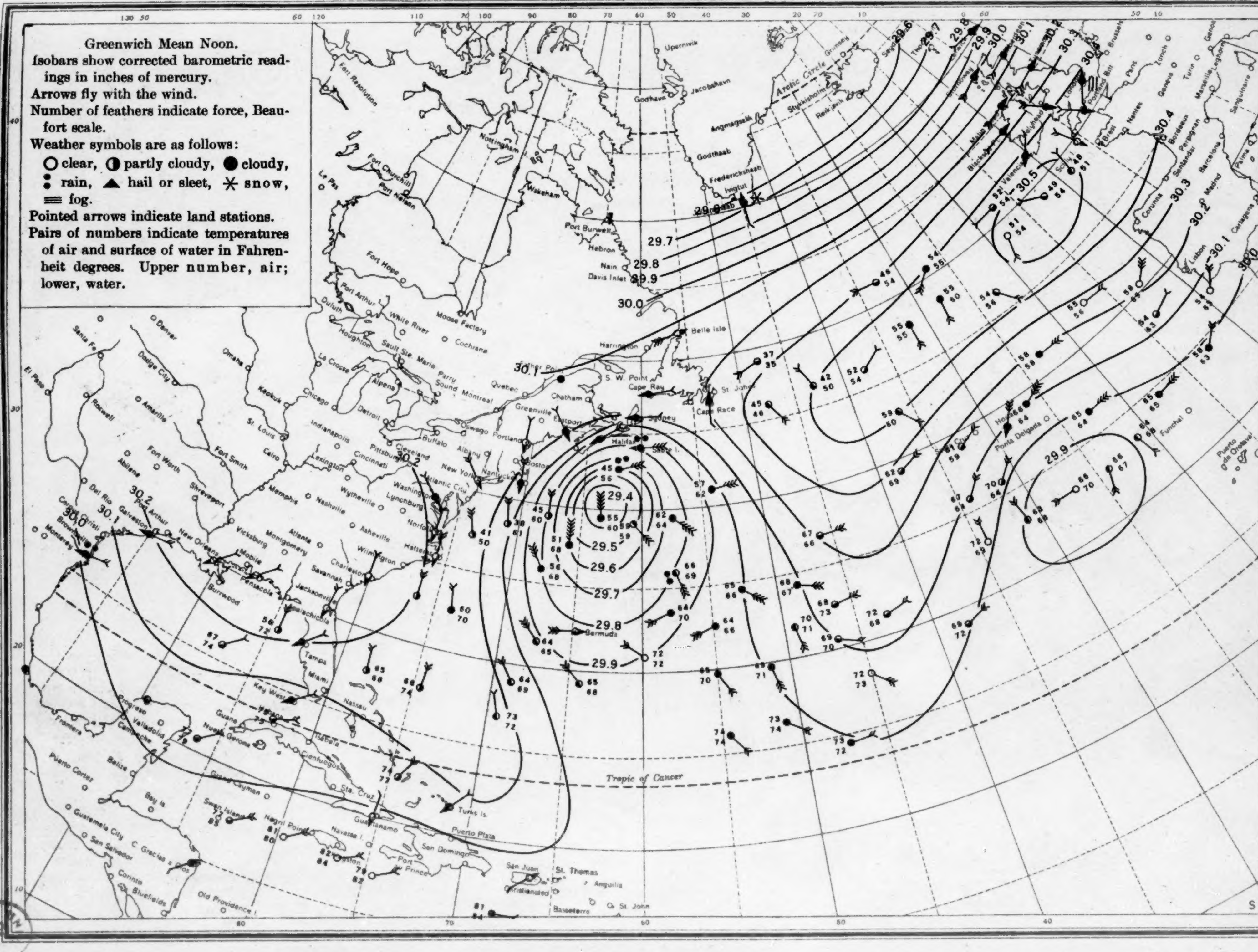


Chart XIII. Weather Map of North Atlantic Ocean, January 11, 1931
(Plotted by F. A. Young)